

Science Standards of Learning Curriculum Framework

Introduction

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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The 2003 *Science Standards of Learning Curriculum Framework* can be found in PDF and Microsoft Word file formats on the Virginia Department of Education's Web site at <http://www.pen.k12.va.us/VDOE/Instruction/sol.html>

Science

Standards of Learning Curriculum Framework

The *Science Standards of Learning Curriculum Framework* amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The *Science Curriculum Framework* provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

School divisions should use the *Science Curriculum Framework* as a resource for developing sound curricular and instructional programs. This framework should not limit the scope of instructional programs. Additional knowledge and skills that can enrich instruction and enhance students' understanding of the content identified in the Standards of Learning should be included as part of quality learning experiences.

The Board of Education recognizes that school divisions will adopt a K–12 instructional sequence that best serves their students. The design of the Standards of Learning assessment program, however, requires that all Virginia school divisions prepare students to demonstrate achievement of the standards for elementary and middle school by the time they complete the grade levels tested. The high school end-of-course Standards of Learning tests, for which students may earn verified units of credit, are administered in a locally determined sequence.



Science Standards of Learning Curriculum Framework

Kindergarten

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Kindergarten Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standard K.1 represent more specifically what a student should achieve during the course of instruction in kindergarten. Across the grade levels, the skills in the first standards form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence.”) It is important that the classroom teacher understands how the skills in standards K.1 and K.2 are a key part of this sequence (i.e., 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the “Scientific Investigation, Reasoning, and Logic” strand.

Strand: Scientific Investigation, Reasoning, and Logic

Standard K.1

The student will conduct investigations in which

- a) basic properties of objects are identified by direct observation;
- b) observations are made from multiple positions to achieve different perspectives;
- c) objects are described both pictorially and verbally;
- d) a set of objects is sequenced according to size;
- e) a set of objects is separated into two groups based on a single physical attribute;
- f) nonstandard units are used to measure common objects;
- g) a question is developed from one or more observations;
- h) picture graphs are constructed using 10 or fewer units;
- i) an unseen member in a sequence of objects is predicted; and
- j) unusual or unexpected results in an activity are recognized.

Understanding the Standard

The skills defined in K.1 are intended to develop the investigative and inquiry components of all of the other kindergarten standards (i.e., K.2–K.10). Standard K.1 describes the range of inquiry skills and the level of proficiency in using those skills that students should achieve in the context of science concepts developed in kindergarten. Standard K.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other kindergarten science standards. It is also intended that by participating in activities and experiences that develop these skills, students will achieve a preliminary understanding of scientific inquiry and the nature of science and more fully grasp the content-related concepts.

Standard K.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Observation is an important way to learn about the world. Through observation one can learn to compare, contrast, and note similarities and differences.• An object can appear very different depending on how it is oriented. To describe an object fully and accurately, it should be observed from several different positions.• Putting objects in a sequence allows one to understand how things are related. A sequence can show how things can change a little at a time.• Picture graphs are useful ways to display and report information.• A nonstandard unit of measure, such as the length of a paper clip, can be used to describe and communicate the dimensions of an object. For the nonstandard unit to be most useful, it should be consistent and easily applied.• Observations about familiar objects or events often lead to the development of important questions that can spark further investigation.• Observations can be communicated through pictures and discussions.• It is important to observe the results of an investigation carefully. Results that are unexpected or unusual may be of interest for further study.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• observe objects and describe their basic properties. These include color, shape (circle, triangle, square, and rectangle), size (big, little, large, small), texture (rough, smooth, hard, soft), and weight (heavy, light).• observe an object or objects from multiple positions to achieve different perspectives. In order to accomplish this, the student should look at the object from top, bottom, front, and back.• arrange a set of objects in sequence according to size.• separate a set of objects into two groups based on a single physical attribute, including size, color, texture, and weight.• construct picture graphs using 10 or fewer units.• measure common objects with nonstandard units. Examples of nonstandard units include hands, pennies, and paper clips.• predict an unseen member in a sequence of objects to complete a pattern.• develop a question from one or more observations.• describe objects both pictorially and verbally.• identify unusual or unexpected results in an activity.

Strand: Scientific Investigation, Reasoning, and Logic

Standard K.2

Students will investigate and understand that humans have senses that allow one to seek, find, take in, and react or respond to information in order to learn about one's surroundings. Key concepts include

- a) five senses and corresponding sensing organ (taste – tongue, touch – skin, smell – nose, hearing – ears, and sight – eyes); and
- b) sensory descriptors (sweet, sour, bitter, salty, rough/smooth, hard/soft, cold, warm, hot, loud/soft, high/low, bright/dull).

Understanding the Standard

The second standard at the kindergarten level is very closely related to the inquiry skill of observation developed in K.1. This standard focuses on the senses — sight, smell, hearing, touch, and taste. Standard K.2 focuses on student understanding that each sensing organ (eyes, ears, nose, tongue, and skin) is associated with a sense. It is important to emphasize that one should never taste, touch, or sniff something when the identity is unknown or has any potential danger.

Standard K.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• A particular sensing organ (eyes, ears, nose, tongue, and skin) is associated with each of the five senses.• Using the senses, we can make careful observations about the world and communicate those observations through descriptors.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify and describe the five senses: taste, touch, smell, hearing, and sight.• match each sensing organ (eyes, ears, nose, tongue, and skin) with its associated sense.• match sensory descriptors with the senses (taste: sweet, sour, bitter, salty; touch: smooth, hard, soft, cold, warm, hot; hearing: loud, soft, high, low; sight: bright, dull, color, black, and white.)

Kindergarten Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard K.3

The student will investigate and understand that magnets have an effect on some materials, make some things move without touching them, and have useful applications. Key concepts include

- a) attraction/nonattraction, push/pull, attract/repel, and metal/nonmetal; and
- b) useful applications (refrigerator magnet, can opener, magnetized screwdriver, and magnetic games).

Understanding the Standard

Magnets have an effect on certain metals and can cause objects to move without physically touching them. Standard K.3 focuses on developing a basic understanding of magnetism that will be expanded in standards 2.2 and 4.3. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Magnets will attract certain metals (iron-bearing, nickel, and cobalt).• Magnets have an effect on some items and can cause them to move. Some items are not affected by magnets and remain stationary.• Because some metals are attracted to magnets, magnets have many simple useful applications in the home.• The force of a magnet can move something without actually touching it.• Repulsion is the force that pushes like poles of magnets apart.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• predict and test which common objects will be attracted to magnets and which will not be attracted to magnets.• classify objects as being attracted or not attracted to magnets, such as iron nail, iron-bearing paper clip, cereal, and book.• explain in their own words essential vocabulary, including the concepts of attraction/nonattraction, push/pull, attract/repel, and metal/nonmetal.• identify items in the home that contain a magnet or magnets, such as can openers, magnetized screwdrivers, magnetic games, and refrigerator magnets.• evaluate the importance and usefulness of magnets in the home.

Kindergarten Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

Strand: Matter

Standard K.4

The student will investigate and understand that the position, motion, and physical properties of an object can be described. Key concepts include

- a) colors (red, orange, yellow, green, blue, purple), white, and black;
- b) shapes (circle, triangle, square, and rectangle) and forms (flexible/stiff, straight/curved);
- c) textures (rough/smooth) and feel (hard/soft);
- d) relative size and weight (big/little, large/small, heavy/light, wide/thin, long/short); and
- e) position (over/under, in/out, above/below, left/right) and speed (fast/slow).

Understanding the Standard

Standard K.4 focuses on student understanding that all objects have physical properties, which include color, shape or form, texture, and size. Position and speed, though not physical properties, can also be observed and described. A basic understanding of physical properties provides a foundation for observing, investigating, and studying matter. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• An object may have many properties that can be observed and described.• Objects can be described readily in terms of color, shape, and texture.• An object can be described according to its position relative to another object and according to its motion.• Two different objects can have some of the same physical properties and some different physical properties.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify and name eight basic colors, including red, orange, yellow, green, blue, and purple. (Indigo and violet are not required at the kindergarten level.) Black and white are not spectral colors, but students should recognize them by name.• identify and name a circle, triangle, square, and rectangle.• compare and contrast objects that are flexible, stiff, straight, and curved.• compare and contrast objects that are rough, smooth, hard, and soft.• compare objects using the concepts of heavy/light, long/short, wide/thin, big/little, and large/small.• measure objects, using nonstandard units.• identify the position of an object, using position words <i>over/under, in/out, above/below, and left/right</i>.• group objects according to their speed — fast or slow.

Strand: Matter

Standard K.5

The student will investigate and understand that water flows and has properties that can be observed and tested. Key concepts include

- a) water occurs in different states (solid, liquid, gas);
- b) the natural flow of water is downhill; and
- c) some materials float in water, while others sink.

Understanding the Standard

Standard K.5 focuses on student understanding that water has identifying properties that can be observed and described. This standard serves as a basis for understanding physical properties and states of matter. Related primary standards include 1.3, 2.3, and 3.3. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Water can be a solid, liquid, or gas.• The state of water can be changed by heating or cooling it.• The natural flow of water is from a higher to a lower level.• Some objects float in water, while others do not.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify examples of the different states of water (solid, liquid, and gas).• classify examples of different states of matter as solid, liquid, or gas.• describe the natural flow of water.• predict where a stream of water will flow.• predict whether items will float or sink when placed in water. Items to use include wood, metal, fruits, paper, and plastics.

Kindergarten Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, 1.4, 1.5, 2.4, 3.4, and 4.4.

Strand: Life Processes

Standard K.6

The student will investigate and understand basic needs and life processes of plants and animals. Key concepts include

- a) living things change as they grow, and they need food, water, and air to survive;
- b) plants and animals live and die (go through a life cycle); and
- c) offspring of plants and animals are similar but not identical to their parents and to one another.

Understanding the Standard

Standard K.6 focuses on student understanding that all living things have basic life needs and life processes. This standard introduces basic life science concepts that progress through high school Biology. K.6 is very closely related to the concepts presented in 1.4 and 1.5. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Plants and animals change as they grow.• Plants and animals need food, water, and gases in the air to live. (Many animals and plants that live in water use the gases that are dissolved in the water.)• Plants and animals live and die. This is part of the life cycle.• Many offspring of plants and animals are like their parents but not identical to them.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe the life needs of animals and plants. The life needs are food, water, and air.• predict what will happen to animals and plants if life needs are not met.• describe some simple changes animals and plants undergo during the life cycle. For animals this may include changes in color, body covering, and overall size. For plants this may include size, presence of leaves and branches, and ability to produce flowers and fruits.• compare and contrast young plants and animals with their parents, using pictures and/or live organisms.

Kindergarten Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of relationships within and among Earth and space systems. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard K.7

The student will investigate and understand that shadows occur when light is blocked by an object. Key concepts include

- a) shadows occur in nature when sunlight is blocked by an object; and
- b) shadows can be produced by blocking artificial light sources.

Understanding the Standard

Standard K.7 focuses on student understanding that shadows are produced when objects block light. This is a key concept for student's future understanding of more complex Earth and physical science concepts such as night and day and eclipses. Within the primary grades, related concepts are found in standards 1.6 and 3.8. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• A shadow is an image of an object created when light is blocked by that object.• Shadows can occur whenever light is present.• People can make shadows.• Living and nonliving things can make shadows.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify a shadow or variety of shadows.• describe how to make a shadow.• identify and describe sources of light — sun, electric lights, and flashlights — that can produce shadows.• match objects with the shadow they would create.• analyze how shadows change as the direction of the light source changes.

Kindergarten Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards K.8, K.9, 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

Strand: Earth Patterns, Cycles, and Change

Standard K.8

The student will investigate and understand simple patterns in his/her daily life. Key concepts include

- a) weather observations;
- b) the shapes and forms of many common natural objects including seeds, cones, and leaves;
- c) animal and plant growth; and
- d) home and school routines.

Understanding the Standard

Standard K.8 focuses on student understanding of basic patterns in daily life. Careful observations of patterns help predict events. Patterns are found in weather; in natural objects, including seeds, cones, and leaves; in the growth of animals and plants; and in daily routines. The basic kindergarten concepts related to patterns will be further developed in the primary grades, especially basic concepts of cycles, sequences, and rate. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• One can make simple predictions in weather patterns. On a cloudy, warm day, it may rain. On a cloudy day that is very cold, it may snow. On a clear day there most likely will be no rain or snow.• As animals and plants grow, they get larger according to a pattern.• Natural objects such as leaves, seeds, and cones have patterns we can see.• Home and school routines frequently follow a pattern.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• observe and identify daily weather conditions — sunny, rainy, cloudy, snowy, windy, warm, hot, cool, and cold.• predict daily weather based on basic observable conditions.• chart daily weather conditions.• identify simple patterns in natural objects — veins in a leaf, spiral patterns in cones, shapes and colors of common seeds.• identify and describe patterns in their daily schedule at home.• identify and describe patterns in their daily schedule at school.• distinguish between the patterns in home activities and those in school activities.• describe how animals and plants change as they grow. (Related to K.6.)

Strand: Earth Patterns, Cycles, and Change

Standard K.9

The student will investigate and understand that change occurs over time and rates may be fast or slow. Key concepts include

- a) natural and human-made things may change over time; and
- b) changes can be noted and measured.

Understanding the Standard

Almost everything changes over time. Those changes can be observed and measured. Standard K.9 focuses on student understanding of the basic aspects of change, especially in those things that can be easily observed and are within the experience of kindergarten children. Change is a key concept woven into most of the science standards throughout elementary, middle, and high school. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.9

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Change occurs over time.• Change can be fast or slow depending upon the object and conditions.• As people grow, they change.• Not all things change at a rate that can be observed easily.• Many changes can be measured.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify some changes that people experience over time — e.g., height, weight, and color of hair.• predict how their own height and weight will change over the school year.• describe how people cause things to change — e.g., demolition of buildings, construction of buildings, cutting down trees, planting trees, and building highways.• describe how things change naturally. This includes seasonal changes, the growth in seeds and common plants, common animals, including the butterfly, and the weather.• identify examples of fast changes and slow changes. Slow changes should be the kinds of familiar changes that occur over weeks, months, or seasons. Students are not responsible for long-term changes.

Kindergarten Science Strand

Resources

This strand focuses on student understanding of the role of natural resources and how people can utilize those resources in a sustainable way. Resource management is an important idea developed within the strand. This begins with basic ideas of conservation and proceeds in the sixth grade to the more abstract consideration of costs and benefits. The topics developed include the conservation of household materials, the importance of soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards K.10, 1.8, 2.8, 3.10, 3.11, 4.8, and 6.9.

Strand: Resources

Standard K.10

The student will investigate and understand that materials can be reused, recycled, and conserved. Key concepts include

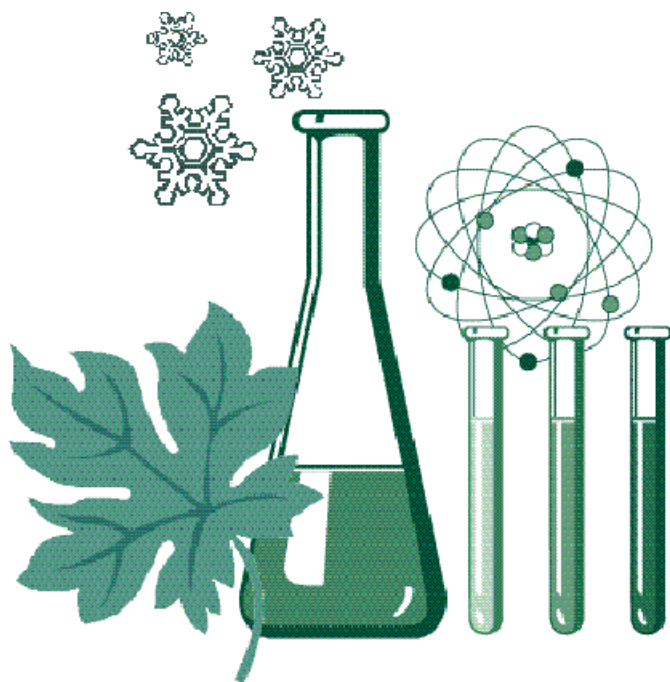
- a) materials and objects can be used over and over again;
- b) everyday materials can be recycled; and
- c) water and energy conservation at home and in school helps preserve resources for future use.

Understanding the Standard

Standard K.10 focuses on student understanding that materials can be reused, recycled, and conserved. This should include common objects and materials found in the school and home environment. K.10 establishes a foundation for increasingly advanced conservation concepts developed in the primary standards. Note that science standard 1.8 is very closely related to K.10. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (K.1 and K.2) in the context of the key concepts presented in this standard.

Standard K.10

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Natural resources such as water and energy should be conserved.• Recycling helps to save our natural resources. Recycling recovers used materials. Many materials can be recycled and used again, sometimes in different forms. Examples include newspapers that are turned into writing tablets.• Reusing materials means using them more than once. Examples include using dishes and utensils that are washed after use rather than using paper plates and plastic utensils and putting them in the trash.• Recycling, reusing, and conserving helps preserve resources for future use.• Resources will last longer if we recycle, reuse, and reduce consumption.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• give examples of objects, such as paper, plastic containers, and glass containers, that can be recycled.• identify materials that can be reused.• describe the difference between recycle and reuse.• name ways to conserve water and energy.• describe how to recycle a given material — paper, oil, aluminum, glass and plastics.• predict what would happen if recycling and reusing were not practiced.



Science Standards of Learning Curriculum Framework

Grade One

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Grade One Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 1.1 represent more specifically what a student should achieve during the course of instruction in the first grade. Across the grade levels, the skills in the first standards form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence”). It is important that the classroom teacher understands how the skills in standard 1.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the “Scientific Investigation, Reasoning, and Logic” strand.

Strand: Scientific Investigation, Reasoning, and Logic

Standard 1.1

The student will conduct investigations in which

- a) differences in physical properties are observed using the senses;
- b) simple tools are used to enhance observations;
- c) objects or events are classified and arranged according to attributes or properties;
- d) observations and data are communicated orally and with simple graphs, pictures, written statements, and numbers;
- e) length, mass, and volume are measured using standard and nonstandard units;
- f) predictions are based on patterns of observation rather than random guesses;
- g) simple experiments are conducted to answer questions; and
- h) inferences are made and conclusions are drawn about familiar objects and events.

Understanding the Standard

The skills described in standard 1.1 are intended to define the “investigate” component of all other first grade standards (1.2–1.8). The intent of standard 1.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the first grade. Standard 1.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all other first grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related SOL concepts.

Standard 1.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• To communicate an observation accurately, one must provide a clear description of exactly what is observed and nothing more.• Simple tools, such as a magnifying glass, ruler, and thermometer, can extend the observations that people can make.• Graphs are powerful ways to display data, making it easier to recognize important information. Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.• Standard measures are important for describing an object because standard measures are recognized by everyone. Many nonstandard measures, such as hand or finger length, vary considerably.• An <i>inference</i> is a conclusion based on evidence about events that have already occurred.• A <i>prediction</i> is a forecast about what <i>may</i> happen in some future situation. It is based on information and evidence. A prediction is different from a guess.• An <i>experiment</i> is a fair test designed to answer a question.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• use their senses and simple tools, such as a magnifying glass, ruler, and thermometer, to enhance their observations of physical properties.• classify and arrange objects or events according to at least two attributes or properties so that similarities and differences become apparent.• communicate observations made and data collected orally and with simple graphs, pictures, written statements, and numbers.• measure length, mass, and volume, using standard and nonstandard units and appropriate instruments. By the third grade, students will be expected to have basic facility with metric measures, including centimeters, grams, and liters.• use familiar events and objects to make inferences and draw conclusions.• predict outcomes based on actual observations and evidence rather than random guesses.

Standard 1.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
	<ul style="list-style-type: none">• answer questions by conducting simple experiments/investigations, using simple tools, such as thermometer, ruler, or magnifying glass. A simple experiment is one that changes only one thing at a time (tests only one variable), gives quick results, and provides easily observable changes.

Grade One Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard 1.2

The student will investigate and understand that moving objects exhibit different kinds of motion. Key concepts include

- a) objects may have straight, circular, and back-and-forth motions;
- b) objects may vibrate and produce sound;
- c) pushes or pulls can change the movement of an object; and
- d) the motion of objects may be observed in the manipulation toys and in playground activities.

Understanding the Standard

Physical science includes topics that give students a chance to increase their understanding of the characteristics of objects and materials that they encounter daily. Knowledge about objects develops through learning how they move and change position and shape in relation to the viewer, as when we look at objects from different angles. Students learn about objects by observing them and noting similarities and differences and by acting on them by applying force. This concept relates to science standard K.3, in which magnets push and pull objects. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• An object's motion may be described by tracing and measuring its position over time. The motion of objects may be straight, circular, curved, or back-and-forth.• One kind of back-and-forth motion is vibration. Vibrations may create sound.• Pushing or pulling can change the position and motion of objects. For the same object, the size of the change is related to the strength of the push or pull.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• make and communicate observations about moving objects. Examples should include balls, objects with wheels, windup toys, tops, rubber bands, and playground equipment.• predict an object's movement, using its size, shape, and the force of the push or pull on it.• conduct a simple experiment to determine an object's movement.• describe and classify the motion of an object as straight, circular, curved, or back-and-forth.• understand that vibrations may create sound, such as humming, strumming a guitar, or plucking a rubber band.• record observations of movement (length/distance), using standard (English/metric) and nonstandard units.• compare the movement of objects, using graphs, pictures, and/or numbers.

Grade One Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

Standard 1.3

The student will investigate and understand how different common materials interact with water. Key concepts include

- a) some liquids will separate when mixed with water, but others will not;
- b) some common solids will dissolve in water, but others will not; and
- c) some substances will dissolve more readily in hot water than in cold water.

Understanding the Standard

Students continue their study of water by examining and qualitatively describing water and its behavior with other matter. When carefully observed, described, and measured, the properties of objects in or with water, and the changes that occur when materials interact with water, provide the necessary foundation for more abstract ideas in the upper grade levels. This concept is related to science standard K.5 in which students identify water in its different states (solid, liquid, gas). It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Different types of materials react differently when mixed with water.• Some liquids will mix with water, while others will not.• Some solids will dissolve in water, while others will not.• The temperature of the water affects how easily a substance will dissolve in it.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe and apply the term <i>dissolve</i>.• predict and describe how various materials (vinegar, milk, baking soda, powdered drink mix, sugar, salt, sand, oil, soil, rocks) act when mixed with water.• classify liquids and solids into those that will dissolve in water and those that will not. Use picture graphs, tables, and/or charts to record and display the information.• infer that some substances will dissolve more easily in hot water than in cold water by conducting investigations using water at different temperatures.

Grade One Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, 1.4, 1.5, 2.4, 3.4, and 4.4.

Strand: Life Processes

Standard 1.4

The student will investigate and understand that plants have life needs and functional parts and can be classified according to certain characteristics. Key concepts include

- a) needs (food, air, water, light, and a place to grow);
- b) parts (seeds, roots, stems, leaves, blossoms, fruits); and
- c) characteristics (edible/nonedible, flowering/nonflowering, evergreen/deciduous).

Understanding the Standard

Young children have a natural curiosity about the living things that they encounter. Observation is a method by which students can answer questions about how plants live, their parts, and characteristics. All plants need nourishment, air, and a place to grow. They have specific structures to meet their needs. Students need to know the concepts, not the definitions, of the terms *edible*, *nonedible*, *evergreen*, and *deciduous*. They need to know that we eat certain plants (edible) but not others (nonedible). They need to know that some plants stay green all year long (evergreen) while others lose their leaves each fall (deciduous). The concepts in this standard build upon the Life Processes strand (K.6), in which students investigate and understand basic needs and life processes of plants and animals. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Plants have basic needs, including food, air, water, light, and a place to grow.• Plants have different structures that serve different functions in growth, survival, and reproduction.• The functions of plant parts include roots holding plants in place and absorbing water, seeds making new plants, leaves making food for the plant, and stems holding the plants upright and transporting materials up and down the plant.• Plants can be categorized by their different characteristics, such as edible/nonedible, flowering/nonflowering, and evergreen/deciduous. Students do not need to know the terms <i>nonedible</i>, <i>edible</i>, <i>evergreen</i>, and <i>deciduous</i>. The focus should be on the concept, not the terminology.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• conduct simple experiments/investigations related to plant needs by changing one variable (food, air, water, light, or place to grow) at a time. Students do not need to know the term <i>variable</i>.• create and interpret a model/drawing of a plant, including seeds, roots, stems, leaves, blossoms, and fruits.• identify the functions of the seed, root, stem, and leaf.• classify plants by the characteristics of edible/nonedible, flowering/nonflowering, and evergreen/deciduous, using tables, charts, and picture graphs.

Strand: Life Processes

Standard 1.5

The student will investigate and understand that animals, including people, have life needs and specific physical characteristics and can be classified according to certain characteristics. Key concepts include

- a) life needs (air, food, water, and a suitable place to live);
- b) physical characteristics (body coverings, body shape, appendages, and methods of movement); and
- c) other characteristics (wild/tame, water homes/land homes).

Understanding the Standard

This standard focuses on the idea that animals move, need food, breathe, and reproduce. Animals have a variety of ways in which they accomplish these activities. Each type of animal has features that allow it to function in unique and specific ways to obtain food, reproduce, and survive in a particular place. This standard builds upon the Life Processes strand (K.6), in which students investigate and understand basic needs and life processes of plants and animals. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none"> • Animals, including people, have basic life needs, including air, food, water, and a suitable place to live. • Body coverings include hair, fur, feathers, scales, and shells. • Appendages are parts, such as arms, legs, wings, fins, and tails, that extend from the main body and that have specific functions. Students do not need to know the term <i>appendage</i>. The focus should be on the concept, not the terminology. • Methods of movement may include walking, crawling, flying, and swimming. • Simple ways to classify animals are whether they are wild or tame and whether they live on land or in water. 	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none"> • make and communicate observations of live animals, including people, about their needs, physical characteristics, and where they live. • describe the life needs of animals, including air, food, water, and a suitable place to live. • identify and chart simple characteristics by which animals can be classified, including body coverings (hair, fur, feathers, scales, and shells), body shape, appendages (arms, legs, wings, fins, and tails), methods of movement (walking, crawling, flying, and swimming), wild or tame, and water homes or land homes. • distinguish between wild animals (raccoon, hawk, squirrel, shark) and tame animals (dog, cat, sheep) and recognize examples of each. • infer types of animal homes (water or land), using the physical characteristics of the animals, such as scales and fins that allow fish to live and move in water or fur and legs that allow dogs to live and move on land. • classify animals by where they live (their homes).

Grade One Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of relationships within and among Earth and space systems. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard 1.6

The student will investigate and understand the basic relationships between the sun and the Earth. Key concepts include

- a) the sun is the source of heat and light that warms the land, air, and water; and
- b) night and day are caused by the rotation of the Earth.

Understanding the Standard

This standard focuses on some of the important relationships between the sun and the Earth. Day and night occur because Earth turns or rotates on its axis. Earth turns on its axis once a day. Students need to understand the concepts of rotation and axis, but they do not need to know the terms. This standard builds upon science standard K.7 about light and shadow. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The sun is the source of light on Earth.• The sun provides heat, which warms the land, air, and water on Earth.• The rotation of Earth means that Earth turns once a day. The part of Earth facing the sun has daytime and the part not facing the sun has nighttime.• Rotation of the Earth causes day and night.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• infer that sunlight striking an object makes the object warmer.• conduct simple experiments to show how sunlight changes the temperature of land, air, and water.• demonstrate and describe the concept of rotation.• comprehend that day and night are caused by Earth's rotation.• compare and contrast day and night by characteristic changes in temperature and light.• model the rotation of Earth and its physical relationship to the sun.• interpret the relationship between the sun's position in the sky and the general time of day. This includes the sun's relative position in the morning (East), at noon, and in the late afternoon (West).

Grade One Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards K.8, K.9, 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

Strand: Earth Patterns, Cycles, and Change

Standard 1.7

The student will investigate and understand the relationship of seasonal change and weather to the activities and life processes of plants and animals. Key concepts include how temperature, light, and precipitation bring about changes in

- a) plants (growth, budding, falling leaves, and wilting);
- b) animals (behaviors, hibernation, migration, body covering, and habitat); and
- c) people (dress, recreation, and work).

Understanding the Standard

The focus of this standard is on temperature, light, and precipitation as they relate to life changes in plants, animals, and people. There are many ways to acquaint children with Earth science-related phenomena that they will come to understand later as being cyclic, and this standard introduces those ideas. It is enough for young children to observe the pattern of daily changes without getting deeply into the nature of climate. They should notice how these changes affect plants and animals. This is observable and can be charted over short and intermediate time periods. Students need to understand the concepts of migration, hibernation, and habitat, but they do not necessarily need to know the terms at first grade. This standard builds upon science standard K.8 in which students investigate and understand simple patterns in their daily lives. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Seasonal changes bring about changes in plants, animals, and people.• With seasonal changes come changes in weather, including temperature, light, and precipitation.• Precipitation includes rain, snow, and ice.• Changes in plants include budding, growth, wilting, and losing leaves.• Some animals hibernate and some animals migrate as a result of seasonal changes, resulting in changes in habitat.• The body coverings of some animals change with the seasons. This includes thickness of fur and coloration.• Changes in people include their dress, recreation, and work.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify types of precipitation as rain, snow, and ice and the temperature conditions that result in each one.• relate a temperature and precipitation chart to the corresponding season (daily or weekly).• measure and chart changes in plants, including budding, growth, wilting, and losing leaves. Recognize in what season budding and wilting will most likely occur.• predict how an outdoor plant would change through the seasons.• compare and contrast the four seasons of spring, summer, fall (autumn) and winter in terms of temperature, light, and precipitation.• compare and contrast the activities of some common animals (e.g., squirrels, chipmunks, butterflies, bees, ants, bats, and frogs) during summer and winter by describing changes in their behaviors and body covering.• compare and contrast how some common plants (e.g., oak trees, pine trees, and lawn grass) appear during summer and winter.

Standard 1.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
	<ul style="list-style-type: none">• comprehend the concepts of hibernation, migration, and habitat, and describe how these relate to seasonal changes. (It may be useful to recognize common Virginia animals that hibernate and migrate, but specific names of animals is not the focus of student learning here.)• infer from people’s dress, recreational activities, and work activities what the season is.

Grade One Science Strand

Resources

This strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards K.10, 1.8, 2.8, 3.10, 3.11, 4.8, and 6.9.

Strand: Resources

Standard 1.8

The student will investigate and understand that natural resources are limited. Key concepts include

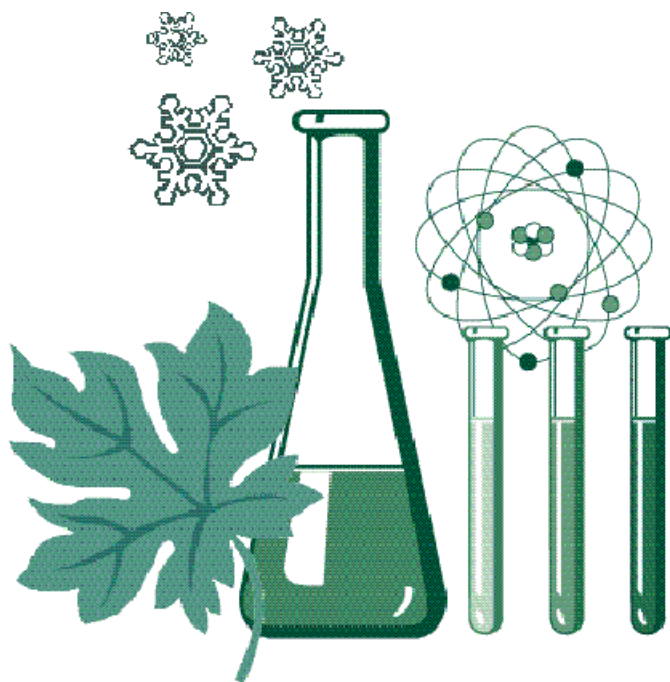
- a) identification of natural resources (plants and animals, water, air, land, minerals, forests, and soil);
- b) factors that affect air and water quality; and
- c) recycling, reusing, and reducing consumption of natural resources.

Understanding the Standard

This standard focuses on identifying what natural resources are; basic ways we can help conserve those natural resources, especially water and air; and the preservation of land to use as parks. The standard extends the perception of young students from the present to the future and from self to their community. Standard K.10 establishes a foundation for this standard. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (1.1) in the context of the key concepts presented in this standard.

Standard 1.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Natural resources provide us with the things we need in order to live, including food, clothing, water, air, shelter, land, and energy.• Many natural resources are limited and cannot be renewed. Other resources are limited and cannot be renewed, but they may last a very long time.• What we put into the air, especially the products of the fuels we burn, affects the quality of the air. Animal, including human, and factory wastes can affect the quality of water. Some pollution washes from yards, streets, and farms.• Recycling recovers used materials. Many materials can be recycled and used again, sometimes in different forms.• Resources will last longer if we recycle them, reuse them, or reduce consumption of them.• The creation of parks can help preserve land. Parks have many uses, including recreation.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify natural resources such as plants and animals, water, air, land, minerals, forests, and soil.• recognize that many natural resources are limited.• compare and contrast ways of conserving resources. This includes recycling, reusing, and reducing consumption of natural resources.• classify factors that affect air and water quality.• describe ways students and schools can help improve water and air quality in our communities.• determine some basic factors that affect water quality by conducting simple investigations in the school environment. Students should be able to make and record observations of what happens to runoff water on rainy days. (Related to 1.3.)• predict what would happen if natural resources were used up, and explain ways to prevent this from happening.• discuss the value of parks to wildlife and to people.



Science Standards of Learning Curriculum Framework

Grade Two

Commonwealth of Virginia
Board of Education
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Grade Two Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 2.1 represent more specifically what a student should achieve during the course of instruction in the second grade. Across the grade levels, the skills in the first standards form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence.”). It is very important that the second grade classroom teacher be familiar with the skills in the sequence leading up to standard 2.1. For example in K.1, nonstandard units are used to measure common objects, and in 1.1, standard and nonstandard units are used. In grade two, 2.1 specifies metric and English units of measure. A second grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the “Scientific Investigation, Reasoning, and Logic” strand.

Strand: Scientific Investigation, Reasoning, and Logic

Standard 2.1

The student will conduct investigations in which

- a) observation is differentiated from personal interpretation, and conclusions are drawn based on observations;
- b) observations are repeated to ensure accuracy;
- c) two or more attributes are used to classify items;
- d) conditions that influence a change are defined;
- e) length, volume, mass, and temperature measurements are made in metric units (centimeters, meters, liters, degrees Celsius, grams, kilograms) and standard English units (inches, feet, yards, cups, pints, quarts, gallons, degrees Fahrenheit, ounces, pounds);
- f) pictures and bar graphs are constructed using numbered axes;
- g) unexpected or unusual quantitative data are recognized; and
- h) simple physical models are constructed.

Understanding the Standard

The skills defined in standard 2.1 are intended to define the “investigate” component of all of the other second grade standards. Standard 2.1 require students to continue developing a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the second grade. Standard 2.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other second grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

Standard 2.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The more times an observation is repeated, the greater the chance of ensuring the accuracy of the observation.• In order to communicate accurately, it is necessary to provide a clear description of exactly what is observed. There is a difference between what one can observe and what can be interpreted from an observation.• It is easier to see how things are related if objects are classified according to their common characteristics.• By constructing and studying simple models, it is sometimes easier to understand how real things work.• Scientific investigations require standard measures, reliable tools, and organized collection and reporting of data. The way the data are displayed can make it easier to interpret important information.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• conduct simple experiments, make predictions, gather data from those experiments, repeat observations to improve accuracy, and draw conclusions.• classify items, using two or more attributes such as size, shape, color, texture, and weight.• differentiate among simple observations and personal interpretations. This requires students to comprehend what an observation is and apply the term in novel situations related to second grade SOL concepts.• construct and interpret simple models (for example, weathering and erosion of land surfaces — 2.7).• analyze sets of objects, numerical data, or pictures, and create basic categories to organize the data (descriptive or numerical).• construct and interpret picture and bar graphs with numbered axes depicting the distribution of data.• use centimeters, meters, liters, degrees Celsius, grams, and kilograms in measurement.• use inches, feet, yards, quarts, gallons, degrees Fahrenheit, ounces, and pounds in measurement.

Standard 2.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
	<ul style="list-style-type: none">• judge which, if any, collected data in a small set appear to be unexpected or unusual.

Grade Two Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard 2.2

The student will investigate and understand that natural and artificial magnets have certain characteristics and attract specific types of metals. Key concepts include

- a) magnetism, iron, magnetic/nonmagnetic, poles, attract/repel; and
- b) important applications of magnetism including the magnetic compass.

Understanding the Standard

This standard continues the focus on magnets. In K.3 students investigate and learn that magnets can be used to make some things move without touching them by either attracting them or repelling them. In 2.2, magnets are revisited and students investigate and understand that magnets can be artificial or natural and have certain characteristics. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Magnets can attract objects made of iron or nickel.• Magnets can be artificially made from special metals or can occur naturally. Naturally occurring magnets are composed of a mineral called magnetite (lodestone).• When a magnetized metal, such as a compass needle, is allowed to swing freely, it displays the interesting property of aligning with the Earth's magnetic fields.• Magnets have a north and a south pole.• Unlike magnetic poles attract, and like poles repel.• Magnets have important applications and uses in everyday life.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• predict which materials will be attracted to magnets, test the predictions, and create a chart that shows the results, classifying materials as to whether they are attracted to magnets or not.• compare natural magnets (lodestone or magnetite) and artificial magnets.• identify the north and south magnetic poles of magnets.• conduct an investigation to determine how the different poles of magnets react to the poles of other magnets.• use magnetic compasses to determine the directions of north and south poles.• identify important applications of magnets in everyday life:<ul style="list-style-type: none">- refrigerator magnets and chalkboard letters- toys- door latches- paper clip holders.• create a new application for using a magnet.

Grade Two Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

Strand: Matter

Standard 2.3

The student will investigate and understand basic properties of solids, liquids, and gases. Key concepts include

- a) mass and volume; and
- b) processes involved with changes in matter from one state to another (condensation, evaporation, melting, and freezing).

Understanding the Standard

This standard continues to focus on matter. In 2.3 students build upon the knowledge introduced in K.4 and 1.3. In K.4 physical properties of matter are investigated and the properties of water are observed and tested. In 1.3 students investigate how common materials interact with water. In 2.3 students investigate, by conducting simple experiments, the properties of solids, liquids, and gases. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• All common substances are made of matter.• <i>Matter</i> is anything that has mass and takes up space.• <i>Mass</i> is a measure of the amount of matter.• <i>Volume</i> is the measure of the amount of space occupied by matter.• Matter most commonly occurs in three states: solids, liquids, and gases.• Matter can change from one state to another.• When matter changes from one state to another, these changes are referred to as physical changes.• Changes from solid to liquid to gas require heat energy.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• classify materials as to whether they are liquids, solids, or gases.• measure the mass of solids and the volume of liquids in metric and standard English units.• design an investigation to determine basic factors that affect the evaporation of water.• examine and describe the transformation of matter from one state to another, i.e., solid water (ice) to liquid (water) to gas (steam).• conduct an investigation to observe the condensation of water.• describe and identify examples of condensation, evaporation, melting, and freezing of water.• identify the uses of water in the home and at school.

Grade Two Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, 1.4, 1.5, 2.4, 3.4, and 4.4.

Strand: Life Processes

Standard 2.4

The student will investigate and understand that plants and animals undergo a series of orderly changes in their life cycles. Key concepts include

- a) some animals (frogs and butterflies) undergo distinct stages during their lives, while others generally resemble their parents; and
- b) flowering plants undergo many changes, from the formation of the flower to the development of the fruit.

Understanding the Standard

In 2.4 students investigate and understand that plants and animals undergo change throughout their lives. This concept builds upon K.6, in which students learn about the basic needs and life processes of animals, and 1.4, in which they learn that plants have life needs and functional parts and can be classified according to certain characteristics. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Throughout their lives, plants and animals undergo a series of orderly and identifiable changes.• Changes in living things over time occur in cycles and differ among the various plants and animals.• Some animals, such as frogs and butterflies, go through distinct stages as they mature to adults. Other animals, such as deer, resemble their parents from birth to maturity and do not have distinct stages.• An important part of the life cycle of a flowering plant is the formation of the flower to the development of the fruit.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe changes in the life cycle of a frog and a butterfly.• identify and describe changes in a plant from flower (blossom) to fruit.• compare and contrast life cycles of a frog and a butterfly.• construct and interpret models/diagrams of animal and plant life cycles.

Grade Two Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living things and a general classifying of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

Strand: Living Systems

Standard 2.5

The student will investigate and understand that living things are part of a system. Key concepts include

- a) living organisms are interdependent with their living and nonliving surroundings; and
- b) habitats change over time due to many influences.

Understanding the Standard

In K.6 students are introduced to the concept of living and nonliving. Students are introduced to living systems in 2.5 and investigate and understand that living things interact with other living things and their surroundings. The formal word *system* is introduced in this standard. The expectation is that students understand the concept in terms of the interactions between living and nonliving things. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Living things are dependent on other living things and their nonliving surroundings for survival.• All of the interactions between and among living things and their nonliving surroundings are referred to as a <i>system</i>.• Shelter may be living (coral, tree) or nonliving (caves, houses).• The habitats of living things, such as forests, grasslands, rivers, and streams, change due to many influences. Habitats change from season to season.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• classify objects as to whether they are living or nonliving.• describe the nonliving components of an organism's surroundings, including water, space, and shelter. (Shelter may be living or nonliving.)• construct and interpret simple models of different kinds of habitats, including a forest and a stream.• predict and describe seasonal changes in habitat and their effects on plants and animals, for example, how trees change through the seasons and how animals respond to changes in the seasons.• describe how animals are dependent on their surroundings, for example, how squirrels and other animals are affected by the loss of forest habitat.

Grade Two Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard 2.6

The student will investigate and understand basic types, changes, and patterns of weather. Key concepts include

- a) temperature, wind, precipitation, drought, flood, and storms; and
- b) the uses and importance of measuring and recording weather data.

Understanding the Standard

In K.8 students conduct weather observations, and in 1.6 and 1.7 students are introduced to the concept that the sun is the source of heat and light for the Earth, and to the ways heat, light, and precipitation affect people and other living things. In 2.6 students investigate and understand types of weather and weather patterns and measure and record weather data. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The Earth’s weather changes continuously from day to day.• Changes in the weather are characterized by daily differences in wind, temperature, and precipitation. Precipitation occurs when water, previously evaporated, condenses out of the air and changes state from a gas to a liquid (rain) or to a solid (snow or sleet).• Extremes in the weather, such as too little or too much precipitation, can result in droughts or floods.• Storms have powerful winds, which may be accompanied by rain, snow, or other kinds of precipitation.• Weather data is collected and recorded using instruments. This information is very useful for predicting weather and determining weather patterns.• Weather influences human activity.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• observe and describe types of precipitation, including rain, snow, and ice (sleet and hail).• observe and describe precipitation in terms of evaporation and condensation of water.• observe and record daily weather conditions, such as sunny, cloudy, windy, rainy, or snowy.• describe weather in terms of temperature, wind, and precipitation.• measure and record weather data, using weather instruments, including a thermometer, rain gauge, and weather vane (standard English and metric measures).• record and interpret daily temperature, using a graph with numbered axes.• observe and describe seasonal weather patterns and local variations.• identify common types of storms. Examples include hurricanes, tornadoes, blizzards, and thunderstorms.• compare and contrast droughts and floods.• evaluate the influence of daily weather conditions on personal activities and dress.

Grade Two Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards K.8, K.9, 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

Strand: Earth Patterns, Cycles, and Change

Standard 2.7

The student will investigate and understand that weather and seasonal changes affect plants, animals, and their surroundings. Key concepts include

- a) effects on growth and behavior of living things (migration, hibernation, camouflage, adaptation, dormancy); and
- b) weathering and erosion of the land surface.

Understanding the Standard

Students are introduced to the concepts of patterns, cycles, and change in standards K.8 and K.9. These concepts include, in K.8, weather observations, shapes and forms of common natural objects (seeds, cones, and leaves), animal and plant growth, and home and school routine. K.9 introduces concepts that include natural and human-made things that change over time, either fast or slow, and that change can be measured. In 1.7 students investigate and understand the relationship between seasonal change and weather. Important concepts include how plants, animals, and people respond to changes in light, temperature, and precipitation. In 2.7 the students investigate and understand that weather and seasons affect plants, animals, and their surroundings. The effects of weather and seasonal changes on weathering and erosion of the land surface are included in 2.7. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Living things respond to weather and seasonal changes. This can be reflected in changes in growth and behavior.• Adverse conditions of weather may slow the growth and development of plants and animals (<i>dormancy</i>), whereas optimal weather conditions may accelerate the growth and development of plants and animals.• Many trees produce new leaves in the spring and lose them in the fall due to seasonal changes in temperature and light.• The outward coloration and coloration patterns of many animals are similar in appearance to the plants in the places in which they live. This similarity to background is referred to as <i>camouflage</i>, and it enables animals to hide and avoid those that may eat or harm them.• Some animals travel from one place to another and back again (<i>migration</i>) or go into a deep sleep (<i>hibernation</i>) due to seasonal changes.• Some animals (geese, monarch butterflies) migrate. Some animals (bears, groundhogs) hibernate. Some animals undergo physical changes (thickening of dog fur in the winter and shedding in the summer) from season to season.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify growth and behavioral responses of plants and animals to weather and seasonal changes. Examples of responses that are adaptive include migration, hibernation, and dormancy.• identify animals that migrate, hibernate, or show other changes throughout the seasons or in the presence of adverse environmental conditions.• evaluate the usefulness of camouflage in an animal's habitat (for example, coloration patterns in frogs).• compare and contrast the responses of plants and animals to weather and seasonal changes.• model the effects of weathering and erosion on the land surface.

Standard 2.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Land surfaces are subject to the agents of weathering and erosion. Land surfaces that are not covered with or protected by plants are more likely to be subject to the loss of soil by wind and water.• <i>Weathering</i> is the breaking down of rocks.• <i>Erosion</i> is the process by which the products of weathering are moved from one place to another.	

Grade Two Science Strand

Resources

This strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards K.10, 1.8, 2.8, 3.10, 3.11, 4.8, and 6.9.

Strand: Resources

Standard 2.8

The student will investigate and understand that plants produce oxygen and food, are a source of useful products, and provide benefits in nature. Key concepts include

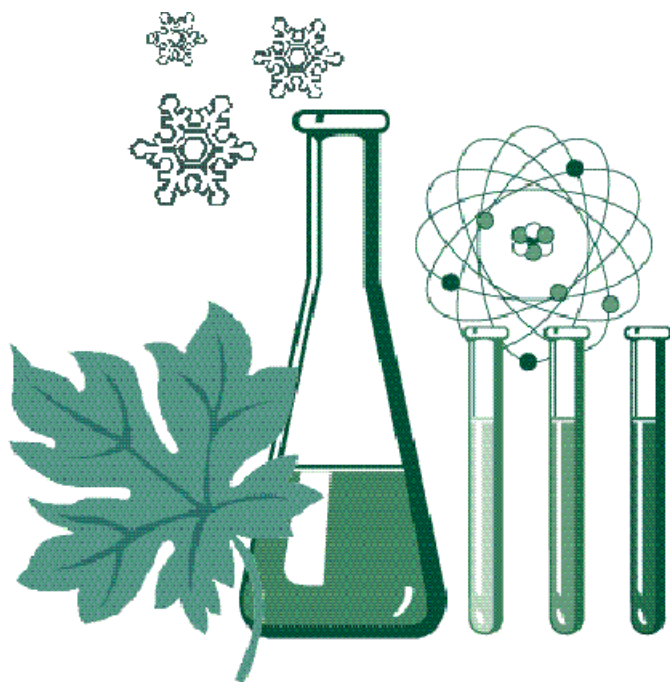
- a) important plant products (fiber, cotton, oil, spices, lumber, rubber, medicines, and paper);
- b) the availability of plant products affects the development of a geographic area; and
- c) plants provide homes and food for many animals and prevent soil from washing away.

Understanding the Standard

In K.10 students investigate and understand that materials can be used, recycled, and conserved, while in 1.8 students investigate and understand that natural resources, which are identified as plants, animals, water, air, land, minerals, forests, and soil, are limited. In 2.8 students investigate and understand that plants produce oxygen and food, are a source of useful products, and provide benefits in nature. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (2.1) in the context of the key concepts presented in this standard.

Standard 2.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Plants provide many useful products and materials, which benefit human beings as well as other living things.• Plant products include such essentials as oxygen and food, as well as materials useful for clothing and shelter.• Plants may grow well only in certain geographic areas, thus enabling the production of plant products that allow humans to live in as well as to develop those areas.• Plants provide homes and food for many animals.• Plants are also important agents in the prevention of soil erosion.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• comprehend that plants produce oxygen and food.• classify and identify the sources and uses of plant products, such as fiber, cotton, oil, spices, lumber, rubber, medicines, and paper.• describe plant products grown in Virginia that are useful to people, including wood, fruits, and vegetables. List and classify plant products.• compare and contrast different ways animals use plants as homes and shelters.• construct and interpret a chart illustrating the plant foods consumed by different animals.• construct and interpret a model that demonstrates how plants prevent soil erosion.



Science Standards of Learning Curriculum Framework

Grade Three

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Board of Education
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Grade Three Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 3.1 represent more specifically what a student should be able to do as a result of science experiences in third grade. Across the grade levels, the skills in the “Scientific Investigation, Reasoning, and Logic” strand form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence.”) It is important that the classroom teacher understands how the skills in standard 3.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The third grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the “Scientific Investigation, Reasoning, and Logic” strand.

Strand: Scientific Investigation, Reasoning, and Logic

Standard 3.1

The student will plan and conduct investigations in which

- a) predictions and observations are made;
- b) objects with similar characteristics are classified into at least two sets and two subsets;
- c) questions are developed to formulate hypotheses;
- d) volume is measured to the nearest milliliter and liter;
- e) length is measured to the nearest centimeter;
- f) mass is measured to the nearest gram;
- g) data are gathered, charted, and graphed (line plot, picture graph, and bar graph);
- h) temperature is measured to the nearest degree Celsius;
- i) time is measured to the nearest minute;
- j) inferences are made and conclusions are drawn; and
- k) natural events are sequenced chronologically.

Understanding the Standard

The skills defined in standard 3.1 are intended to define the “investigate” component of all of the other third grade standards (3.2–3.11). The intent of standard 3.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the third grade. Standard 3.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other third grade standards. For example, it is not expected that teachers should develop a separate unit on the metric system, but that they should integrate metric measurement into the teaching of the rest of the third grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

Standard 3.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none"> • Questions frequently arise from observations. Hypotheses can be developed from those questions. Data gathered from an investigation may support a hypothesis. • Complete observations are made using all of the senses. Simple instruments can help extend the senses. • <i>Predictions</i> are statements of what is expected to happen in the future based on past experiences and observations. • In order for data from an investigation to be most useful, it must be organized so that it can be examined more easily. • Charts and graphs are powerful tools for reporting and organizing data. • It is sometimes useful to organize objects according to similarities and differences. By organizing objects in sets and subsets, it may be easier to determine a specific type of characteristic. • An <i>inference</i> is a conclusion based on evidence. • Putting natural events in a sequence allows us to notice change over time. • Metric measures, including centimeters, grams, milliliters, and degrees Celsius, are a standard way to record measurements. The metric system is recognized everywhere around the world. 	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none"> • develop hypotheses from simple questions. These questions should be related to the concepts in the third grade standards. Hypotheses should be stated in terms such as: “If an object is cut into smaller pieces, then the physical properties of the object and its smaller pieces will remain the same.” • make and communicate predictions about the outcomes of investigations. • make and communicate careful observations. • communicate results of investigations by displaying data in the form of tables, charts, and graphs. Students will construct bar and picture graphs and line plots to display data. (Example: 3.7 — comparison of types of soil and their effect on plant growth) • classify objects into at least two major sets and subsets based on similar characteristics, such as predator/prey and herbivore, carnivore, and omnivore. • sequence natural events chronologically. (Example: 3.9 — plant and animal life cycles, phases of the moon, the water cycle, and tidal change)

Standard 3.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• A bar graph can be horizontal or vertical, and it compares amounts. Both the X- and Y-axis need to be identified. Discrete data are found on a bar graph.• A line plot shows the spread of data. (<i>See Grade 3 Mathematics Curriculum Framework, Standard 3.21, page 32.</i>)• A picture graph is similar to a bar graph except that it uses symbols to represent quantities.	<ul style="list-style-type: none">• measure length to the nearest centimeter, mass to the nearest gram, volume to the nearest milliliter, temperature to the nearest degree Celsius, and time to the nearest minute, using the appropriate instrument.

Grade Three Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard 3.2

The student will investigate and understand simple machines and their uses. Key concepts include

- a) types of simple machines (lever, screw, pulley, wheel and axle, inclined plane, and wedge);
- b) how simple machines function;
- c) compound machines (scissors, wheelbarrow, and bicycle); and
- d) examples of simple and compound machines found in the school, home, and work environment.

Understanding the Standard

This standard introduces students to six types of simple machines, their uses, and examples of these six machines found in everyday environments. These simple machines function to make doing work easier. Activities should focus on identifying the six simple machines, explaining how they operate, and locating examples in everyday life that make a task easier at home, in school, and in the workplace. The students should have experiences using the simple and compound machines to determine how each makes a task easier. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Simple machines are tools that make work easier. Examples of tasks made easier include lifting a heavy weight, moving a heavy object over a distance, pushing things apart, changing the direction of a force, or holding an object together.• The six simple machines are the lever, inclined plane, wedge, wheel and axle, screw, and pulley.• The <i>lever</i> is a stiff bar that moves about a fixed point (fulcrum). It is a simple machine that is used to push, pull, or lift things. Examples include a seesaw, crowbar, and shovel.• The <i>inclined plane</i> is a flat surface that is raised so one end is higher than the other. The inclined plane helps move heavy objects up or down. An example is a ramp.• The <i>wedge</i> is wide at one end and pointed at the other to help cut or split other objects. Examples include a knife or ax.• The <i>wheel and axle</i> consists of a rod attached to a wheel. A wheel and axle makes it easier to move or turn things. Examples include bicycle wheels, roller skates, and a doorknob.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify and differentiate the six types of simple machines: lever, screw, pulley, wheel and axle, inclined plane, and wedge.• analyze the application of and explain the function of each of the six types of simple machines. An example would be that an inclined plane is a ramp to make it easier for a heavy object to be moved up or down.• differentiate and classify specific examples of simple machines found in school and household items. These include a screwdriver, nutcracker, screw, flagpole pulley, ramp, and seesaw.• design and construct an apparatus that contains a simple machine.• identify and classify the simple machines which compose a compound machine, such as scissors, wheelbarrow, and bicycle.

Standard 3.2 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• The <i>screw</i> is an inclined plane wrapped around a cylinder or cone. A common use of the screw is to hold objects together. Examples include a jar lid and wood screw.• The <i>pulley</i> is a wheel that has a rope wrapped around it. Pulleys can be used to lift heavy objects by changing the direction or amount of the force. Examples include a flagpole.• A compound machine is a combination of two or more simple machines. Examples include scissors, wheelbarrow, and bicycle.	

Grade Three Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

Standard 3.3

The student will investigate and understand that objects are made of materials that can be described by their physical properties. Key concepts include

- a) objects are made of one or more materials;
- b) materials are composed of parts that are too small to be seen without magnification; and
- c) physical properties remain the same as the material is reduced in size.

Understanding the Standard

Students should understand that all objects are made of materials that have observable physical properties. Every object that takes up space is made of matter. Materials can be different colors, shapes, textures, or sizes. They can be hard or soft. The properties of objects can be used to sort or classify them. If materials are broken down into smaller parts, each of these smaller parts still has the same physical properties as the original material. (Clear examples include plastics, metal, paper, and ice. Substances that are coarse mixtures, i.e., many types of rock, are not good examples.) This standard introduces the concept that materials are made up of smaller parts that are too small to be seen without magnification. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Objects are made of one or more materials.• All materials are composed of parts too small to be seen without magnification.• Physical properties remain the same even if the material (e.g., plastic, paper, metal, ice) is reduced in size.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• infer that objects are made of one or more materials based on observations of the physical properties that are common to each individual object.• compare the physical properties of smaller pieces of a material to those physical properties of the entire material.• conclude that materials have their own set of physical properties that are observable.• explain that physical properties are observable characteristics that enable one to differentiate objects.• design an investigation to determine if the physical properties of a material will remain the same if the material is reduced in size.

Grade Three Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, 1.4, 1.5, 2.4, 3.4, and 4.4.

Strand: Life Processes

Standard 3.4

The student will investigate and understand that behavioral and physical adaptations allow animals to respond to life needs. Key concepts include

- a) methods of gathering and storing food, finding shelter, defending themselves, and rearing young; and
- b) hibernation, migration, camouflage, mimicry, instinct, and learned behavior.

Understanding the Standard

Students will compare and contrast the physical and behavioral characteristics of different animals that allow the animals to adapt and respond to life needs. The students will need to describe specific examples of how animals gather food, find shelter, defend themselves, and rear young. The concepts of hibernation, migration, camouflage, mimicry, instinct, and learned behavior are specific ways in which animals respond to their environment. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Physical adaptations help animals survive in their environment. Examples include camouflage and mimicry.• Behavioral adaptations allow animals to respond to life needs. Examples include hibernation, migration, instinct, and learned behavior.• In order to survive, animals act in different ways to gather and store food, find shelter, defend themselves, and rear their young.• Some animals go into a deep winter sleep in which their body activities slow down and they can live off stored food (hibernation).• Some animals go on a long-distance journey from one place to another as seasons change (migration).• Various animals blend into their environments to protect themselves from enemies (camouflage).• Some animals look like other animals to avoid being eaten (mimicry). This adaptation helps protect them from their predators. (For example, the viceroy butterfly tastes good to birds, but the monarch butterfly tastes bad. Because the viceroy looks like the monarch butterfly, it is safer from predators.)	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe and explain the terms <i>hibernation</i>, <i>migration</i>, <i>camouflage</i>, <i>mimicry</i>, <i>instinct</i>, and <i>learned behavior</i>.• give examples of methods that animals use to gather and store food, find shelter, defend themselves, and rear young.• compare the physical characteristics of animals, and explain how the animals are adapted to a certain environment.• explain how an animal's behavioral adaptations help it live in its specific habitat.• design and construct a model of a habitat for an animal with a specific adaptation.• distinguish between physical and behavioral adaptations of animals.• create (model) a camouflage pattern for an animal living in a specific dry-land or water-related environment. (Relates to 3.6.)• compare and contrast instinct and learned behavior.

Standard 3.4 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Some animals are born with natural behaviors that they need in order to survive in their environments. These behaviors are not learned but are instinctive, such as a beaver building a dam or a spider spinning a web.• Some behaviors need to be taught in order for the animal to survive, such as a bear cub learning to hunt.	

Grade Three Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living things and a general classifying of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

Strand: Living Systems

Standard 3.5

The student will investigate and understand relationships among organisms in aquatic and terrestrial food chains. Key concepts include

- a) producer, consumer, decomposer;
- b) herbivore, carnivore, omnivore; and
- c) predator and prey.

Understanding the Standard

This standard focuses on student understanding of the food chain in water and land environments. It focuses on the types of relationships among living things and their dependence on each other for survival. The strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include the basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, 1.4, 1.5, 2.4, 3.4, 4.4, and 6.7. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• A food chain shows a food relationship among plants and animals in a specific area or environment.• Terrestrial organisms are found on land habitats such as deserts, grasslands, and forests. Aquatic organisms are found in water habitats such as ponds, marshes, swamps, rivers, and oceans.• A green plant makes its own food from sunlight, air, and water. Green plants are <i>producers</i>.• A <i>consumer</i> is an animal that eats living organisms (plant or animal).• Certain organisms break down decayed plants and animals into smaller pieces that can be used again by living things. These organisms are <i>decomposers</i>.• A food chain, which shows part of a food web, can have an animal that eats only plants (herbivore). It can have an animal that eats only other animals (carnivore). It can also have an animal that eats both plants and animals (omnivore).• An animal can hunt other animals to get its food (predator).• An animal can be hunted by another animal for food (prey).	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• distinguish among producers, consumers, herbivores, omnivores, carnivores, and decomposers.• create and interpret a model of a food chain showing producers and consumers.• explain how a change in one part of a food chain might affect the rest of the food chain.• identify sequences of feeding relationships in a food chain.• differentiate between predators and prey.• infer that most food chains begin with a green plant.

Strand: Living Systems

Standard 3.6

The student will investigate and understand that environments support a diversity of plants and animals that share limited resources. Key concepts include

- a) water-related environments (pond, marshland, swamp, stream, river, and ocean environments);
- b) dry-land environments (desert, grassland, rain forest, and forest environments); and
- c) population and community.

Understanding the Standard

Students should become familiar with several specific examples of aquatic and terrestrial environments and the plants and animals unique to them. The water-related environments to be discussed are the pond, marshland, swamp, stream, river, and ocean, and the dry-land environments to be discussed are the desert, grassland, rain forest, and forest. Water-related and dry-land environments contain many types of plants and animals that often compete for the same natural resources. These resources are often shared. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Water-related environments include those with fresh water or salt water. Examples include ponds, marshes, swamps, streams, rivers, and oceans.• Dry-land environments include deserts, grasslands, rain forests, and forests.• There are distinct differences among pond, marshland, swamp, stream, river, ocean, desert, grassland, rainforest, and forest environments.• A <i>population</i> is a group of organisms of the same kind that lives in the same place. Examples of a population are a group of swans in a pond, a school of fish in a river, and a herd of cattle in the grassland.• A <i>community</i> is all of the populations that live together in the same place. An example of a dry-land community would be a forest made up of trees, squirrels, worms, rabbits, and hawks. An example of a water-related community would be an ocean made up of fish, crabs, and seaweed.• Organisms compete for the limited resources in their specific environment.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe major water-related environments and examples of animals and plants that live in each.• describe major dry-land environments and examples of animals and plants that live in each.• compare and contrast water-related and dry-land environments.• distinguish between a population and a community.• explain how animals and plants use resources in their environment.• analyze models or diagrams of different water-related environments in order to describe the community of organisms each contains and interpret how the organisms use the resources in that environment.• analyze models or diagrams of different dry-land environments in order to describe the community of organisms each contains and interpret how the organisms use the resources in that environment.• predict what would occur if a population in a specific environment were to die.

Grade Three Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard 3.7

The student will investigate and understand the major components of soil, its origin, and importance to plants and animals including humans. Key concepts include

- a) soil provides the support and nutrients necessary for plant growth;
- b) topsoil is a natural product of subsoil and bedrock;
- c) rock, clay, silt, sand, and humus are components of soils; and
- d) soil is a natural resource and should be conserved.

Understanding the Standard

Students should know that most plants grow in soil and that people and many other animals are dependent on plants for food. The nutrients in soil are materials that plants and animals need to live and grow. Soil takes a long time to form; therefore, it should be conserved. Soil is made up of humus, silt, rock, and sand. Humus is decayed (once living) matter in soil. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Soil is important because many plants grow in soil, and it provides support and nutrients for the plants.• Over many years, weather, water, and living things help break down rocks and create soil (weathering).• Nutrients are materials that plants and animals need to live and grow.• Rock, clay, silt, sand, and humus are components of soil.• <i>Topsoil</i> is the upper soil surface and a natural product of subsoil and bedrock. Topsoil is best for plant growth.• <i>Subsoil</i> and <i>bedrock</i> are layers of soil under the topsoil that are formed over a long period of time by the action of water.• Subsoil and bedrock are not as good for growing plants as is topsoil.• <i>Humus</i> is decayed matter in soil. It adds nutrients to the soil. It is located in the topsoil.• <i>Clay</i> contains tiny particles of soil that hold water well and provides nutrients.• <i>Sand</i> is made up of small grains of worn-down rock, has few nutrients, and does not hold water well.• <i>Silt</i> is made up of very small broken pieces of rock. Its particles are larger than clay and smaller than sand.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• observe and recognize that soil, as a natural resource, provides the support and nutrients necessary for plant growth.• explain how soil forms over time.• analyze and describe the different components of soil, including rock fragments, clay, silt, sand, and humus.• comprehend the key terminology related to soil, including <i>humus</i>, <i>nutrients</i>, <i>topsoil</i>, and <i>bedrock</i>.• interpret and illustrate a basic diagram showing major soil layers, including bedrock, subsoil, and topsoil.• design an investigation to compare how different types of soil affect plant growth. This includes organizing data in tables and constructing simple graphs.• collect, chart, and analyze data on soil conservation on the school grounds.• evaluate the importance of soil to people.• describe how soil can be conserved.

Standard 3.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Since soil takes a long time to form, it should be conserved, not wasted.	

Grade Three Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards K.8, K.9, 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

Strand: Earth Patterns, Cycles, and Change

Standard 3.8

The student will investigate and understand basic patterns and cycles occurring in nature. Key concepts include

- a) patterns of natural events (day and night, seasonal changes, phases of the moon, and tides); and
- b) animal and plant life cycles.

Understanding the Standard

This standard focuses on students understanding that many events on Earth happen in cycles or patterns. Examples of these patterns are day turning into night and night into day. Seasons cycle from fall to winter to spring to summer and back to fall. Light reflecting from the sun causes the moon to appear illuminated. The phases of the moon appear in sequence as the moon makes one revolution around the Earth. Seasons are caused by the tilt of the Earth as it revolves around the sun. The main cause of the tides is the gravitational attraction between the Earth and the moon. Plants and animals also undergo life cycles from birth to death. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• A <i>cycle</i> is a repeated pattern. A <i>sequence</i> is a series of events that occur in a natural order.• The pattern of day and night is caused by the rotation of the Earth. One complete rotation occurs every 24 hours. The part of the Earth toward the sun has daylight while the part of the Earth away from the sun has night.• The pattern of seasonal changes takes place because the Earth's axis is tilted toward or away from the sun during its revolution around the sun. The Earth takes 365 days, or one year, to make one revolution.• The cycle of phases of the moon occurs as the moon makes one revolution around the Earth. The shapes we see follow a pattern.• The tides follow a pattern of two high and two low tides every 24 hours. This pattern is caused for the most part by the gravitational attraction between the Earth and the moon.• Plants and animals undergo life cycles. For example, frogs begin as eggs in water. The eggs grow into tadpoles, the tadpoles eventually become frogs, and the adult frogs lay eggs to start the life cycle over again. In the plant life cycle, a seed grows into a new plant that forms seeds. Then the new seeds repeat the life cycle.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain how some events in nature occur in a pattern or cycle, such as the seasons, day and night, phases of the moon, tides, and life cycles.• recognize that the relationships that exist between and among the Earth, sun, and moon result in day and night, seasonal changes, phases of the moon, and the tides.• model and describe how the Earth's rotation causes day and night.• model and describe how the sun's rays strike the Earth to cause seasons.• observe, chart, and illustrate phases of the moon, and describe the changing pattern of the moon as it revolves around the Earth.• analyze data from simple tide tables to determine a pattern of high and low tides.• explain the pattern of growth and change that organisms, such as the butterfly and frog, undergo during their life cycle.

Strand: Earth Patterns, Cycles, and Change

Standard 3.9

The student will investigate and understand the water cycle and its relationship to life on Earth. Key concepts include

- a) the energy from the sun drives the water cycle;
- b) processes involved in the water cycle (evaporation, condensation, precipitation);
- c) water is essential for living things; and
- d) water supply and water conservation.

Understanding the Standard

This standard introduces students to the movement of water on the Earth by evaporation, condensation, and precipitation, which is called the water cycle. All the water on Earth is part of the water cycle. Water is stored in ponds, lakes, streams, rivers, ground water, and oceans. Water is essential to maintain life on Earth and should be conserved as a natural resource. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.9

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The water cycle is the movement of water from the ground to the air and back to the ground by evaporation, condensation, and precipitation. The energy that drives this cycle comes from the sun.• During the water cycle, liquid water is heated and changed to a gas (evaporation). The gas is cooled and changed back to a liquid (condensation). A liquid or a solid falls to the ground as precipitation.• Our water supply on Earth is limited. Pollution reduces the amount of usable water; therefore, the supply should be conserved carefully.• Water is a simple compound essential for life on Earth. Living cells are mostly water. In each cell, the chemicals necessary for life are dissolved in water.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify the sun as the origin of energy that drives the water cycle.• describe the processes of evaporation, condensation, and precipitation as they relate to the water cycle.• construct and interpret a model of the water cycle.• identify major water sources for a community, including rivers, reservoirs, and wells. Describe the major water sources for the local community.• explain methods of water conservation in the home and school.• analyze possible sources of water pollution in their neighborhoods, at school, and in the local community. This includes runoff from over-fertilized lawns and fields, oil from parking lots, eroding soil, and animal waste.• appraise the importance of water to people and to other living things.• realize living things get water from the environment in different ways.

Grade Three Science Strand

Resources

This strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards K.10, 1.8, 2.8, 3.10, 3.11, 4.8, and 6.9.

Standard 3.10

The student will investigate and understand that natural events and human influences can affect the survival of species. Key concepts include

- a) the interdependency of plants and animals;
- b) the effects of human activity on the quality of air, water, and habitat;
- c) the effects of fire, flood, disease, and erosion on organisms; and
- d) conservation and resource renewal.

Understanding the Standard

This standard reinforces the concept that plants and animals are dependent upon each other for survival. Living things depend on other living thing to survive. Human and natural events can change habitats. Natural disasters such as fire, flood, disease, and erosion can kill organisms and destroy their habitats. Methods of ensuring the survival of plant and animal species include specific conservation measures. These are resource renewal, habitat management procedures, and species monitoring practices. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.10

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Every living thing depends on every other living thing to survive. This is called <i>interdependency</i>.• Human actions, such as polluting, can affect the survival of plants and animals.• Natural events, such as fires, floods, diseases, and erosion, can also affect the survival of plant and animal species.• Conservation is the careful use and preservation of our natural resources.• Resource renewal is a conservation practice in which species are protected. An example would be protecting endangered plants by saving their seeds, growing the seeds indoors, and later putting the new plants back in their natural habitats.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain how living things in an area are dependent on each other.• compare and contrast human influences on the quality of air, water, and habitats.• analyze the effects of fire, flood, disease, and erosion on organisms and habitat.• describe how conservation practices can affect the survival of a species.• describe a conservation practice in the local community.

Standard 3.11

The student will investigate and understand different sources of energy. Key concepts include

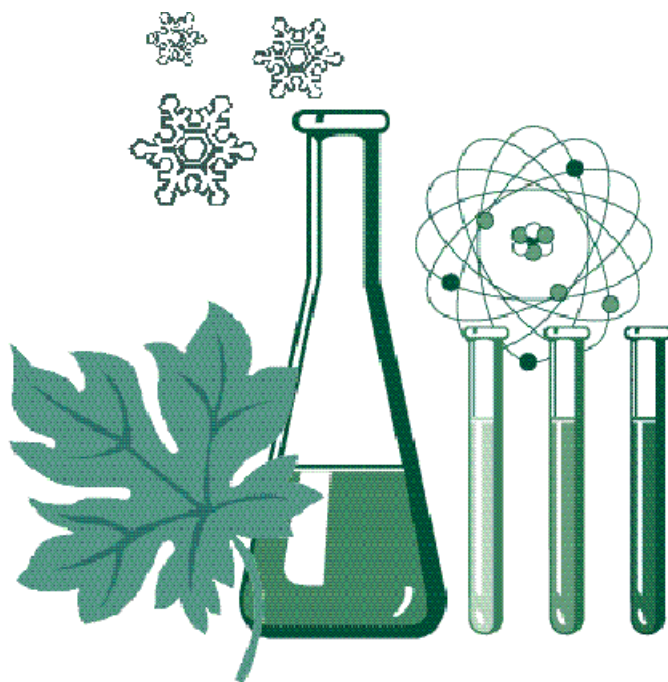
- a) the sun's ability to produce light and heat energy;
- b) sources of energy (sunlight, water, wind);
- c) fossil fuels (coal, oil, natural gas) and wood; and
- d) renewable and nonrenewable energy resources.

Understanding the Standard

This standard focuses on the Earth's major types of energy sources. The sun produces light and heat energy. Natural forms of energy include sunlight, water, and wind. Important fossil fuels are coal, oil, and natural gas, which were formed over millions of years by decaying plants and animals buried in layers of rock. Sources of energy are classified either as renewable or nonrenewable. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (3.1) in the context of the key concepts presented in this standard.

Standard 3.11

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The sun is the source of almost all energy on Earth. The sun is the direct source of light and heat energy.• Sunlight, water, and wind are sources of energy. The force of flowing water and moving air (wind) can also be used to generate electricity.• Wood comes from trees. It has many important uses, including its use as a fuel.• Some energy sources are renewable. That means that they can be replaced. Some energy sources are nonrenewable. That means that once they are used up, they are gone and cannot be replaced. Coal, oil, and natural gas are nonrenewable resources.• Fossil fuels, such as coal, oil, and natural gas, are formed from decayed plants and animals. The formation of fossil fuels takes millions of years.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain that the sun is the major source of energy for the Earth.• analyze the advantages and disadvantages of using different naturally occurring energy sources.• identify sources of energy and their uses.• describe how solar energy, wind, and moving water can be used to produce electricity.• describe how fossil fuels are used as an energy source.• design a basic investigation to determine the effects of sunlight on warming various objects and materials, including water.• compare and contrast renewable and nonrenewable energy sources.



Science Standards of Learning Curriculum Framework

Grade Four

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Board of Education
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Grade Four Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 4.1 represent more specifically what a student should be able to do as a result of science experiences in fourth grade. Across the grade levels, the skills in the “Scientific Investigation, Reasoning, and Logic” strand form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence.”) It is important that the classroom teacher understands how the skills in standard 4.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The fourth grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in this strand.

Strand: Scientific Investigation, Reasoning, and Logic

Standard 4.1

The student will plan and conduct investigations in which

- a) distinctions are made among observations, conclusions, inferences, and predictions;
- b) hypotheses are formulated based on cause-and-effect relationships;
- c) variables that must be held constant in an experimental situation are defined;
- d) appropriate instruments are selected to measure linear distance, volume, mass, and temperature;
- e) appropriate metric measures are used to collect, record, and report data;
- f) data are displayed using bar and basic line graphs;
- g) numerical data that are contradictory or unusual in experimental results are recognized; and
- h) predictions are made based on data from picture graphs, bar graphs, and basic line graphs.

Understanding the Standard

The skills described in standard 4.1 are intended to define the “investigate” component of all of the other fourth grade standards (4.2–4.8). The intent of standard 4.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the fourth grade. Standard 4.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other fourth grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

Standard 4.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• To communicate an observation accurately, one must provide a clear description of exactly what is observed and nothing more. Those conducting investigations need to understand the difference between <i>what is seen</i> and what inferences, conclusions, or interpretations can be drawn from the observation.• An <i>inference</i> is a conclusion based on evidence about events that have already occurred. Accurate observations and evidence are necessary to draw realistic and plausible conclusions.• A scientific <i>prediction</i> is a forecast about what <i>may</i> happen in some future situation. It is based on the application of scientific principles and factual information.• Systematic investigations require standard measures (metric), consistent and reliable tools, and organized reporting of data. The way the data are displayed can make it easier to uncover important information. This can assist in making reliable scientific forecasts of future events.• An <i>experiment</i> is a fair test driven by a hypothesis. A fair test is one in which only one variable is compared. A <i>hypothesis</i> is a prediction about the relationship between variables.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• differentiate among simple observations, conclusions, inferences, and predictions, and correctly apply the terminology in oral and written work. This requires students to comprehend the basic terminology and apply it in novel situations related to fourth grade SOL concepts.• analyze a set of 20 or fewer objects, measures, or pictures; classify them into basic categories to organize the data (descriptive or numerical); and construct bar graphs and line graphs depicting the distribution of those data.• use millimeters, centimeters, meters, kilometers, milliliters, liters, grams, and kilograms in measurement.• choose the appropriate instruments, including centimeter rulers, meter sticks, graduated cylinders, beakers, scales and balances, and Celsius thermometers, for making basic metric measures.• make predictions based on picture graphs, bar graphs, and basic line graphs.

Standard 4.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• In order to conduct an experiment, one must recognize all of the potential variables or changes that can affect its outcome.• A <i>manipulated variable</i> is the factor in an experiment that is altered by the experimenter.• A <i>responding variable</i> is the factor in an experiment that changes as a result of the manipulated variable.	<ul style="list-style-type: none">• create a plausible hypothesis, stated in terms of cause and effect, from a set of basic observations that can be tested. This requires a student to comprehend what “cause and effect” is and to be able to apply that idea in new situations. The application should occur in terms of fourth grade SOL-related concepts or other concrete situations. Hypotheses should be stated in terms such as: “If the water temperature is increased, then the amount of sugar that can be dissolved in it will increase.”• analyze the variables in a simple experiment, and decide which must be held constant (not allowed to change) in order for the investigation to represent a fair test. This requires students to comprehend what “variables” are and to apply that idea in new situations related to fourth grade SOL-related concepts. Variables are either manipulated or responding.• judge which, if any, data in a simple set of results (generally 10 or fewer in number) appear to be considerably outside the expected range. Students should be able to determine the significance of unusual data.

Grade Four Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard 4.2

The student will investigate and understand characteristics and interaction of moving objects. Key concepts include

- a) motion is described by an object's direction and speed;
- b) forces cause changes in motion;
- c) friction is a force that opposes motion; and
- d) moving objects have kinetic energy.

Understanding the Standard

This standard is introduced in first grade and prepares students for a more in-depth study of energy in eighth grade. This standard focuses on the characteristics of moving objects. Key concepts include the effect of forces, such as friction, on moving objects. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The position of an object can be described by locating it relative to another object or to the background.• Tracing and measuring an object's position over time can describe its motion.• <i>Speed</i> describes how fast an object is moving.• Energy may exist in two states: kinetic or potential.• <i>Kinetic energy</i> is the energy of motion.• A <i>force</i> is any push or pull that causes an object to move, stop, or change speed or direction.• The greater the force, the greater the change in motion will be. The more massive an object, the less effect a given force will have on the object.• <i>Friction</i> is the resistance to motion created by two objects moving against each other. Friction creates heat.• Unless acted on by a force, objects in motion tend to stay in motion and objects at rest remain at rest.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe the position of an object.• collect and display in a table and line graph time and position data for a moving object.• explain that speed is a measure of motion.• interpret data to determine if the speed of an object is increasing, decreasing, or remaining the same.• identify the forces that cause an object's motion.• describe the direction of an object's motion: up, down, forward, backward.• infer that objects have kinetic energy.• design an investigation to determine the effect of friction on moving objects.

Strand: Force, Motion, and Energy

Standard 4.3

The student will investigate and understand the characteristics of electricity. Key concepts include

- a) conductors and insulators;
- b) basic circuits (open/closed, parallel/series);
- c) static electricity;
- d) the ability of electrical energy to be transformed into heat, light, and mechanical energy;
- e) simple electromagnets and magnetism; and
- f) historical contributions in understanding electricity.

Understanding the Standard

This standard focuses on the characteristics of electricity as related to circuits and circuit components, magnetism, static charges, and historical contributions important to the understanding of electricity. As electrical energy is an integral part of modern civilization (e.g., powering our computers; lighting, heating and cooling our homes and businesses; and making the information age possible), it is critical that students begin to understand basic electricity concepts. This standard will be the basis for a more in-depth study in the eighth grade. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• A continuous flow of negative charges (electrons) creates an electric <i>current</i>. The pathway taken by an electric current is a <i>circuit</i>. Closed circuits allow the movement of electrical energy. Open circuits prevent the movement of electrical energy.• Electrical energy moves through materials that are <i>conductors</i> (metals). <i>Insulators</i> (rubber, plastic, wood) do not conduct electricity well.• Among conducting materials, energy passes more or less easily because of the material's resistance.• In a series circuit, there is only one pathway for the current, but in a parallel circuit there are two or more pathways for it.• Rubbing certain materials together creates static electricity.• <i>Lightning</i> is the discharge of static electricity in the atmosphere.• Electrical energy can be transformed into heat, light, or mechanical energy.• Certain iron-bearing metals attract other such metals (also nickel and cobalt).• Lines of force extend from the poles of a magnet in an arched pattern defining the area over which magnetic force is exerted.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• apply the terms <i>insulators</i>, <i>conductors</i>, <i>open</i> and <i>closed</i> in describing electrical circuits.• differentiate between an open and closed electric circuit.• use the dry cell symbols (–) and (+).• create and diagram a functioning series circuit using dry cells, wires, switches, bulbs, and bulb holders.• create and diagram a functioning parallel circuit using dry cells, wires, switches, bulbs, and bulb holders.• differentiate between a parallel and series circuit.• create a diagram of a magnetic field using a magnet.• compare and contrast a permanent magnet and an electromagnet.• explain how electricity is generated by a moving magnetic field.• design an investigation using static electricity to attract or repel a variety of materials.• explain how static electricity is created and occurs in nature.• construct a simple electromagnet using a wire, nail, or other iron-bearing object, and a dry cell.

Standard 4.3 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• An electric current creates a magnetic field, and a moving magnetic field creates an electric current.• A current flowing through a wire creates a magnetic field. Wrapping a wire around certain iron-bearing metals (iron nail) and creating a closed circuit is an example of a simple electromagnet.• Benjamin Franklin, Michael Faraday, and Thomas Edison made important discoveries about electricity.	<ul style="list-style-type: none">• design and perform an investigation to determine the strength of an electromagnet. (The manipulated variable could be the number of coils of wire and the responding variable could be the number of paperclips the magnet can attract.)• describe the contributions of Ben Franklin, Michael Faraday, and Thomas Edison to the understanding and harnessing of electricity.

Grade Four Science Strand

Life Processes

This strand focuses on the life processes of plants and animals and the specific needs of each. The major topics developed in the strand include basic needs and life processes of organisms, their physical characteristics, orderly changes in life cycles, behavioral and physical adaptations, and survival and perpetuation of species. This strand includes science standards K.6, 1.4, 1.5, 2.4, 3.4, and 4.4.

Strand: Life Processes

Standard 4.4

The student will investigate and understand basic plant anatomy and life processes. Key concepts include

- a) the structures of typical plants (leaves, stems, roots, and flowers);
- b) processes and structures involved with reproduction (pollination, stamen, pistil, sepal, embryo, spore, and seed);
- c) photosynthesis (sunlight, chlorophyll, water, carbon dioxide, oxygen, and sugar); and
- d) dormancy.

Understanding the Standard

This standard focuses on the basic life processes and anatomy of plants. It represents a more in-depth treatment of the plant structures and the processes associated with plant reproduction. Photosynthesis is introduced in this standard. Closely related standards from previous grades include K.6, 1.4, and 2.4. This standard also is closely connected with concepts presented in science standard 4.5. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• For many typical green plants, there are anatomical structures that perform certain basic functions. For example, roots anchor the plants and take water and nutrients from the soil. Plant stems provide support and allow movement of water and nutrients.• The plant kingdom can be divided into two general groups: those that produce seeds and those that produce spores.• Many seed-producing plants have roots, stems, leaves, and flowers. The stamen and pistil are reproductive parts of the flower. The sepals are the small leaves that form the housing of the developing flower.• Pollination is part of the reproductive process of flowering plants. Pollination is the process by which pollen is transferred from the stamens to the stigma.• Some plants reproduce with spores. These include ferns and mosses.• Green plants produce their own food through the process of photosynthesis. Green plants use chlorophyll to produce food (sugar), using carbon dioxide, water, nutrients, and sunlight. Leaves are the primary food producing part of these plants.• Oxygen is produced during photosynthesis.• Dormancy is a period of suspended life processes brought on by changes in the environment.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• create a model/diagram illustrating the parts of a flower (stamen, pistil, sepal, ovary, ovule, seed) and explain the functions of those parts.• analyze a common plant: identify the roots, stems, leaves, and flowers, and explain the function of each.• create a model/diagram illustrating the reproductive processes in typical flowering plants, and explain the processes.• compare and contrast different ways plants are pollinated.• explain that ferns and mosses reproduce with spores rather than seeds.• explain the process of photosynthesis, using the following terminology: <i>sunlight, chlorophyll, water, carbon dioxide, oxygen, and sugar</i>.• design an investigation to determine the relationship between the presence of sunlight and plant growth.• explain the role of dormancy for common plants.

Grade Four Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living things and a general classifying of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

Strand: Living Systems

Standard 4.5

The student will investigate and understand how plants and animals in an ecosystem interact with one another and the nonliving environment. Key concepts include

- a) behavioral and structural adaptations;
- b) organization of communities;
- c) flow of energy through food webs;
- d) habitats and niches;
- e) life cycles; and
- f) influence of human activity on ecosystems.

Understanding the Standard

This standard focuses on the relationships among plants, animals, and the nonliving environment and brings together several elements of both Life Processes and Living Systems. This standard assumes students have a basic understanding that all living things are interrelated and dependent in some way on other living things and their environment. Plants and animals in ecological systems live in a web of interdependence in which each species contributes to the functioning of the overall system. Organisms live in a habitat to which they are structurally and behaviorally adapted. Certain conditions within environments determine which organisms and communities succeed there. This standard builds upon previous standards 1.5, 2.4, 2.5, 3.4, 3.5 and 3.6. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Organisms have structural adaptations, or physical attributes, that help them meet a life need.• Organisms also have behavioral adaptations, or certain types of activities they perform, which help them meet a life need.• The organization of communities is based on the utilization of the energy from the sun within a given ecosystem. The greatest amount of energy in a community is in the producers.• Within a community, organisms are dependent on the survival of other organisms. Energy is passed from one organism to another.• The organization of a community is defined by the interrelated niches within it.• The sun's energy cycles through ecosystems from producers through consumers and back into the nutrient pool through decomposers.• An organism's habitat provides food, water, shelter, and space. The size of the habitat depends on the organism's needs.	<p>In order to meet this standard, it is expected that students will be able to</p> <ul style="list-style-type: none">• distinguish between structural and behavioral adaptations.• investigate and infer the function of basic adaptations and provide evidence for the conclusion.• understand that adaptations allow an organism to succeed in a given environment.• explain how different organisms use their unique adaptations to meet their needs.• describe why certain communities exist in given habitats.• illustrate the food webs in a local area and compare and contrast the niches of several different organisms within the community.• compare and contrast the differing ways an organism interacts with its surroundings at various stages of its life cycle. Specific examples include a frog and a butterfly.• differentiate among positive and negative influences of human activity on ecosystems.

Standard 4.5 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• A <i>niche</i> is the function that an organism performs in the food web of that community. A niche also includes everything else the organism does and needs in its environment. No two types of organisms occupy exactly the same niche in a community.• During its life cycle, an organism's role in the community — its niche — may change. For example, what an animal eats, what eats it, and other relationships will change.• Humans can have a major impact on ecosystems.• Habitat is the place or kind of place in which an animal or plant naturally lives.	

Grade Four Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard 4.6

The student will investigate and understand how weather conditions and phenomena occur and can be predicted. Key concepts include

- a) weather measurements and meteorological tools (air pressure – barometer, wind speed – anemometer, rainfall – rain gauge, and temperature – thermometer); and
- b) weather phenomena (fronts, clouds, and storms).

Understanding the Standard

This standard focuses on weather conditions and a more technical understanding of the tools and methods used to forecast future atmospheric conditions. Weather is introduced in science standard 2.6. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• <i>Temperature</i> is the measure of the amount of heat energy in the atmosphere.• <i>Air pressure</i> is due to the weight of the air and is determined by several factors including the temperature of the air.• A <i>front</i> is the boundary between air masses of different temperature and humidity.• Cirrus, stratus, cumulus, and cumulo-nimbus clouds are associated with certain weather conditions.• <i>Cumulus clouds</i> are fluffy and white with flat bottoms. They usually indicate fair weather. However, when they get larger and darker on the bottom, they produce thunderstorms.• <i>Stratus clouds</i> are smooth, gray clouds that cover the whole sky (block out direct sunlight). Light rain and drizzle are usually associated with stratus clouds.• <i>Cirrus clouds</i> are feathery clouds. They are associated with fair weather. Cirrus clouds often indicate that rain or snow will fall within several hours.• Extreme atmospheric conditions create various kinds of storms such as thunderstorms, hurricanes, and tornadoes.• Different atmospheric conditions create different types of precipitation.	<p>In order to meet this standard, it is expected that students will be able to</p> <ul style="list-style-type: none">• use a thermometer to compare air temperatures over a period of time.• analyze the changes in air pressure occurring over time, using a barometer, and predict what the changes mean in terms of changing weather patterns.• differentiate between the types of weather associated with high and low pressure air masses. Illustrate and label high and low pressure air masses and warm and cold fronts.• differentiate between cloud types (cirrus, stratus, cumulus, and cumulo-nimbus clouds) and the associated weather.• compare and contrast the formation of different types of precipitation (rain, snow, sleet, and hail).• recognize a variety of storm types, describe the weather conditions associated with each, and explain when they occur (thunderstorms, hurricanes, and tornadoes).• analyze and report information about temperature and precipitation on weather maps.• measure wind speed, using an anemometer.• measure precipitation with a rain gauge.

Standard 4.6 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Meteorologists gather data by using a variety of instruments.• Meteorologists use data to predict weather patterns.• A <i>barometer</i> measures air pressure.• An <i>anemometer</i> measures wind speed.• A <i>rain gauge</i> measures precipitation.• A <i>thermometer</i> measures the temperature of the air.	<ul style="list-style-type: none">• design an investigation in which weather data are gathered using meteorological tools and charted to make weather predictions.

Grade Four Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards K.8, K.9, 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

Strand: Earth Patterns, Cycles, and Change

Standard 4.7

The student will investigate and understand the relationships among the Earth, moon, and sun. Key concepts include

- a) the motions of the Earth, moon, and sun (revolution and rotation);
- b) the causes for the Earth's seasons and phases of the moon;
- c) the relative size, position, age, and makeup of the Earth, moon, and sun; and
- d) historical contributions in understanding the Earth-moon-sun system.

Understanding the Standard

This standard focuses on the Earth-moon-sun system and includes knowledge related to the motions of this system and the results of our unique position in it. This includes the presence of an atmosphere, liquid water, and life. The standard is built on concepts developed in science standards K.7, 1.6, and 3.8 and that will be further expanded in 6.8. A more in-depth study of the Earth's makeup is in standard 5.7. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The Earth completes one revolution around the sun every 365 days. The moon revolves around the Earth about once every month.• Due to its axial tilt, the Earth experiences seasons during its revolution around the sun.• The phases of the moon are caused by its position relative to the Earth and the sun. The phases of the moon include the new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter, and waning crescent.• The sun is an average-sized yellow star, about 110 times the diameter of the Earth. The sun is approximately 4.6 billion years old.• Our moon is a small rocky satellite, having about one-quarter the diameter of the Earth and one-eightieth its mass. It has extremes of temperature, virtually no atmosphere, no water, and no life.• The Earth is one of nine planets that revolve around the sun and comprise the solar system. The Earth, the third planet from the sun, is one of the four rocky inner planets. It is about 150 million kilometers from the sun. (The emphasis is placed on the Earth, rather than the other planets.)	<p>In order to meet this standard, it is expected that students will be able to</p> <ul style="list-style-type: none">• differentiate between rotation and revolution.• describe how the Earth's axial tilt causes the seasons.• model the formation of the eight moon phases, sequence the phases in order, and describe how the phases occur.• describe the major characteristics of the sun, including its approximate size, color, age, and overall composition.• create and describe a model of the Earth-moon-sun system with approximate scale distances and sizes.• compare and contrast an Earth-centered to the sun-centered model of the solar system.• analyze the differences in what Aristotle, Ptolemy, Copernicus, and Galileo observed and what influenced their conclusions.• compare and contrast the surface conditions of the Earth, moon, and sun.• describe a contribution of the NASA Apollo missions to our understanding of the moon.

Standard 4.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• The Earth is a geologically active planet with a surface that is constantly changing. Unlike the other three inner planets (see previous bullet), it has large amounts of life-supporting water and an oxygen-rich atmosphere. The Earth's protective atmosphere blocks out most of the sun's damaging rays.• Our understanding of the solar system has changed from an Earth-centered model of Aristotle and Ptolemy to the sun-centered model of Copernicus and Galileo.• The NASA Apollo missions added greatly to our understanding of the moon.• Our understanding of the sun, moon, and the solar system continues to change with new scientific discoveries.	

Grade Four Science Strand

Resources

This strand focuses on student understanding the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards K.10, 1.8, 2.8, 3.10, 3.11, 4.8, and 6.9.

Strand: Resources

Standard 4.8

The student will investigate and understand important Virginia natural resources. Key concepts include

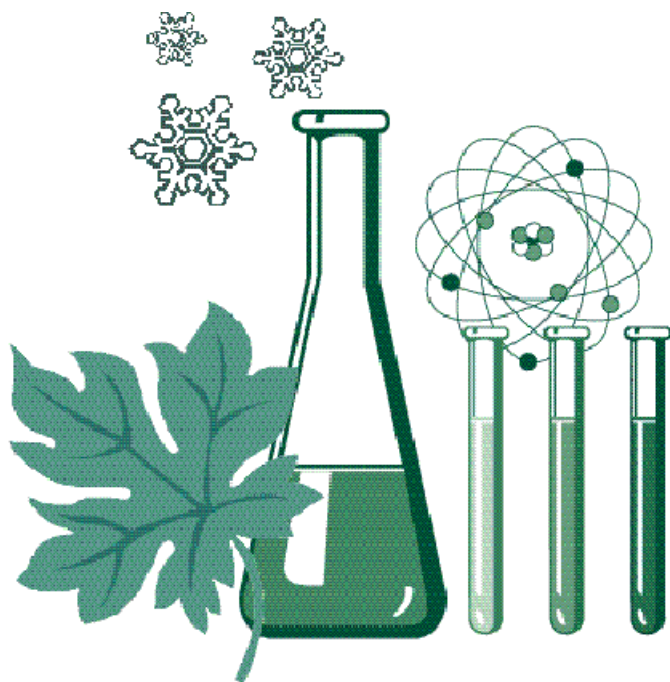
- a) watershed and water resources;
- b) animals and plants;
- c) minerals, rocks, ores, and energy sources; and
- d) forests, soil, and land.

Understanding the Standard

Virginia has a rich variety of natural resources. These provide the raw materials for our daily lives and sustain our economy. Natural resources are finite and must be used wisely to insure their continued availability. This concept of natural resources is introduced in 1.8 and extended in 6.9. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (4.1) in the context of the key concepts presented in this standard.

Standard 4.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Virginia is rich in a wide variety of natural resources, including forests, arable (farmable) land, coal, sand and aggregates (rocks), wildlife and aquatic organisms, clean water and air, and beautiful scenery.• A watershed is an area over which surface water (and the materials it carries) flows to a single collection place. The Chesapeake Bay watershed covers approximately half of Virginia's land area. The other two major watershed systems are the Gulf of Mexico and the North Carolina Sounds.• Virginia's water resources include groundwater, lakes, reservoirs, rivers, bays, and the Atlantic Ocean.• Virginia has a great variety of plant and animal resources.• Natural and cultivated forests are a widespread resource in Virginia.• Virginia's soil and land support a great variety of life, provide space for many economic activities, and offer a variety of recreational opportunities.	<p>In order to meet this standard, it is expected that students will be able to</p> <ul style="list-style-type: none">• compare and contrast natural and man-made resources.• distinguish among rivers, lakes, and bays; describe characteristics of each; and name an example of each in Virginia.• create and interpret a model of a watershed. Evaluate the statement: "We all live downstream."• identify watershed addresses.• recognize the importance of Virginia's mineral resources, including coal, limestone, granite, and sand and gravel.• appraise the importance of natural and cultivated forests in Virginia.• describe a variety of soil and land uses important in Virginia.



Science Standards of Learning Curriculum Framework

Grade Five

Commonwealth of Virginia
Board of Education
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Grade Five Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 5.1 represent more specifically what a student should be able to do as a result of science experiences in fifth grade. Across the grade levels, the skills in the “Scientific Investigation, Reasoning, and Logic” strand form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence.”) It is important that the classroom teacher understands how the skills in standard 5.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The fifth grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed. It is also important to note that 25 percent of items on the third and fifth grade SOL assessments measure the skills defined in the “Scientific Investigation, Reasoning, and Logic” strand.

Strand: Scientific Investigation, Reasoning, and Logic

Standard 5.1

The student will plan and conduct investigations in which

- a) rocks, minerals, and organisms are identified using a classification key;
- b) estimations of length, mass, and volume are made;
- c) appropriate instruments are selected and used for making quantitative observations of length, mass, volume, and elapsed time;
- d) accurate measurements are made using basic tools (thermometer, meter stick, balance, graduated cylinder);
- e) data are collected, recorded, and reported using the appropriate graphical representation (graphs, charts, diagrams);
- f) predictions are made using patterns, and simple graphical data are extrapolated;
- g) manipulated and responding variables are identified; and
- h) an understanding of the nature of science is developed and reinforced.

Understanding the Standard

The skills in standard 5.1 are intended to define the “investigate” component of all of the other fifth grade standards (5.2–5.7). The intent of standard 5.1 is for students to continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the fifth grade. Standard 5.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other fifth grade standards. It is also intended that by developing these skills, students will achieve a greater understanding of scientific inquiry and the nature of science and will more fully grasp the content-related concepts.

Standard 5.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Systematic investigations require standard measures and consistent and reliable tools. Metric measures are a standard way to make measurements and are recognized around the world.• A classification key is an important tool used to help identify objects and organisms. It consists of a branching set of choices organized in levels, with most levels of the key having two choices. Each level provides more specific descriptors, eventually leading to identification.• Systematic investigations require organized reporting of data. The way the data are displayed can make it easier to see important patterns, trends, and relationships. Bar graphs and line graphs are useful tools for reporting discrete data and continuous data, respectively.• A scientific <i>prediction</i> is a forecast about what <i>may</i> happen in some future situation. It is based on the application of factual information and principles and recognition of trends and patterns.• Estimation is a useful tool for making approximate measures and giving general descriptions. In order to make reliable estimates, one must have experience using the particular unit.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• use classification keys to identify rocks, minerals, and organisms.• make plausible estimations of length, mass, and volume.• select and use the appropriate instruments, including centimeter rulers, meter sticks, graduated cylinders, balances, and stopwatches, for making basic measurements.• measure temperature, length, mass, and volume, using metric measures. This includes millimeters, centimeters, meters, kilometers, grams, kilograms, milliliters, liters, and degrees Celsius.• collect, record, and report data, using charts and tables, and translate numerical data into bar or line graphs.• make predictions based on trends in data. This requires the recognition of patterns and trends and determination of what those trends may represent.• analyze the variables in a simple experiment and identify the manipulated (independent) and responding (dependent) variables.• define/make observations and inferences.

Standard 5.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Scientific conclusions are based both on verifiable observations (science is empirical) and on inferences.• <i>Observation</i> is the use of senses to collect information about the environment. <i>Inference</i> is the use of prior knowledge and experience to generate conclusions about those observations.	<ul style="list-style-type: none">• distinguish between observations and inferences.• measure, record, identify, collect, and organize observations. Distinguish between qualitative and quantitative observations.

Grade Five Science Strand

Force, Motion, and Energy

This strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism, types of motion, simple and compound machines, and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard 5.2

The student will investigate and understand how sound is transmitted and is used as a means of communication. Key concepts include

- a) frequency, waves, wavelength, vibration;
- b) the ability of different media (solids, liquids, and gases) to transmit sound; and
- c) uses and applications (voice, sonar, animal sounds, and musical instruments).

Understanding the Standard

This standard introduces the concept of what sound is and how sound is transmitted. The students are introduced to scientific vocabulary and the phenomena of frequency, waves, wavelength, and vibration in this standard. Students should make predictions about and experiment with the transmission of sound. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

Standard 5.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Sound is a form of energy produced and transmitted by vibrating matter.• Sound travels in waves and can be described by the wavelength and frequency of the waves. A <i>wave</i> is a disturbance moving through a medium (solid, liquid, or gas).• The <i>frequency</i> of sound is the number of vibrations in a given unit of time.• Sound is a compression wave moving outward from its source. The <i>wavelength</i> of sound is the distance between two compressions.• <i>Pitch</i> is determined by the frequency of a vibrating object. Objects vibrating faster have a higher pitch than objects vibrating slower.• Sound travels more quickly through solids than through liquids and gases because the molecules of a solid are closer together. Sound travels most slowly through gases because the molecules of a gas are farthest apart.• Some animals make and hear ranges of sound vibrations different from those that humans can make and hear.• Musical instruments vibrate to produce sound.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• use the basic terminology of sound to describe what sound is, how it is formed, how it affects matter, and how it travels.• create and interpret a model or diagram of a compression wave.• explain why sound waves travel only where there is matter to transmit them.• explain the relationship between frequency and pitch.• design an investigation to determine what factors affect the pitch of a vibrating object. This includes vibrating strings, rubber bands, beakers/bottles of air and water, tubes (as in wind chimes), and other common materials.• compare and contrast sound traveling through a solid with sound traveling through the air. Explain how different media (solid, liquid, and gas) will affect the transmission of sound.• compare and contrast the sounds (voice) that humans make and hear to that of other animals. This includes bats, dogs, and whales.• compare and contrast how different kinds of musical instruments make sound. This includes string instruments, woodwinds, percussion instruments, and brass instruments.

Strand: Force, Motion, and Energy

Standard 5.3

The student will investigate and understand basic characteristics of visible light and how it behaves. Key concepts include

- a) the visible spectrum and light waves;
- b) refraction of light through water and prisms;
- c) reflection of light from reflective surfaces (mirrors);
- d) opaque, transparent, and translucent; and
- e) historical contributions in understanding light.

Understanding the Standard

Concepts related to light are introduced at the fifth grade level. Standard 5.3 focuses on the characteristics of visible light, tools that aid in the production and use of light, and the historical contributions of inventors and scientists. Instruction should center on the basic science concerning light energy and how we use light in our daily lives. A related science standard is 4.2, which focuses on forms of energy and provides a foundation for understanding that light is energy. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

Standard 5.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Visible light is a combination of several different wavelengths of light traveling together. These wavelengths are represented by the colors red, orange, yellow, green, blue, indigo, and violet (ROYGBIV).• Light waves are characterized by their wavelengths. In the visible spectrum, red has the longest wavelength, and violet has the shortest. Wavelengths get progressively shorter from red to violet.• Light travels in waves. Compared to sound, light travels extremely fast. It takes light from the sun less than 8½ minutes to travel 150 million kilometers to reach the Earth.• Unlike sound, light waves travel in straight paths called <i>rays</i> and do not need a medium through which to move.• Light travels in straight paths until it hits an object, where it bounces off (is reflected), is bent (is refracted), passes through the object (is transmitted), or is absorbed as heat.• The relative terms <i>transparent</i>, <i>translucent</i>, and <i>opaque</i> indicate the amount of light that passes through an object.• A prism can be used to refract visible light. When the different wavelengths of light in visible light pass through a prism, they are bent at different angles. The colors of light we see are red, orange, yellow, green, blue, indigo, and violet.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain the relationships between wavelength and the color of light. Name the colors of the visible spectrum.• diagram and label a representation of a light wave, including wavelength, peak, and trough.• compare and contrast reflection and refraction, using water, prisms, and mirrors.• explain the terms <i>transparent</i>, <i>translucent</i>, and <i>opaque</i>, and give an example of each.• analyze the effects of a prism on white light and describe why this occurs. Explain why a rainbow occurs.

Grade Five Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

Strand: Matter

Standard 5.4

The student will investigate and understand that matter is anything that has mass, takes up space, and occurs as a solid, liquid, or gas. Key concepts include

- a) atoms, elements, molecules, and compounds;
- b) mixtures including solutions; and
- c) the effect of heat on the states of matter.

Understanding the Standard

This standard incorporates various characteristics of matter such as mass, volume, and the effect of heat on the three states of matter. Instruction should center on the basic structure of matter and how it behaves. This standard builds on standard 3.3, which provides a basis for understanding the structure of matter. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

Standard 5.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• All matter, regardless of its size, shape, or color, is made of particles (atoms and molecules) that are too small to be seen by the unaided eye.• There are more than 100 known elements that make up all matter. The smallest part of an element is an atom.• When two or more elements combine to form a new substance, it is called a <i>compound</i>. There are many different types of compounds because atoms of elements combine in many different ways (and in different whole number ratios) to form different compounds. Examples include water (H₂O) and table salt (NaCl). The smallest part of a compound is a molecule.• A <i>mixture</i> is a combination of two or more substances that do not lose their identifying characteristics when combined. A <i>solution</i> is a mixture in which one substance dissolves in another.• As its temperature increases, many kinds of matter change from a solid to a liquid to a gas. As its temperature decreases, that matter changes from a gas to a liquid to a solid.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• construct and interpret models of atoms, elements, molecules, and compounds.• design an investigation to determine how heat affects the states of matter (e.g., water). Include in the design ways information will be recorded, what measures will be made, what instruments will be used, and ways the data will be graphed.• construct and interpret a sequence of models (diagrams) showing the activity of molecules in all three states of matter.• compare and contrast mixtures and solutions, elements and compounds, and atoms and molecules.

Grade Five Science Strand

Living Systems

This strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of living things and a general classifying of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

Strand: Living Systems

Standard 5.5

The student will investigate and understand that organisms are made of cells and have distinguishing characteristics. Key concepts include

- a) basic cell structures and functions;
- b) kingdoms of living things;
- c) vascular and nonvascular plants; and
- d) vertebrates and invertebrates.

Understanding the Standard

This standard emphasizes the major categories of living things and builds on science standards 2.4 and 4.4. The use of a microscope may be applied to the study of plants, animals, and cells. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

Standard 5.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Living things are made of cells. Cells carry out all life processes. New cells come from existing cells. Cells are too small to be seen with the eye alone. By using a microscope, many parts of a cell can be seen.• Though plant and animal cells are similar, they are also different in shape and in some of their parts. Plant cells tend to be rectangular, while animal cells tend to be spherical or at times irregular.• Organisms that share similar characteristics can be organized into groups in order to help understand similarities and differences.• Living things can be categorized into kingdoms: monerans, protists, fungi, plants, and animals.• Plants can be categorized as vascular (having special tissues to transport food and water — for example, trees and flowering plants) and nonvascular (not having tissues to transport food and water — for example, moss). Most plants are vascular.• Animals can be categorized as vertebrates (having backbones) or invertebrates (not having backbones).	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• draw, label, and describe the essential structures and functions of plant and animal cells. For plants, include the nucleus, cell wall, cell membrane, vacuole, chloroplasts, and cytoplasm. For animals, include the nucleus, cell membrane, vacuole, and cytoplasm.• design an investigation to make observations of cells.• compare and contrast plant and animal cells and identify their major parts and functions.• compare and contrast the distinguishing characteristics of the kingdoms of organisms.• group organisms into categories, using their characteristics: living things (kingdoms), plants (vascular and nonvascular), and animals (vertebrates or invertebrates). Name and describe two common examples of each group.

Grade Five Science Strand

Interrelationships in Earth/Space Systems

This strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard 5.6

The student will investigate and understand characteristics of the ocean environment. Key concepts include

- a) geological characteristics (continental shelf, slope, rise);
- b) physical characteristics (depth, salinity, major currents); and
- c) biological characteristics (ecosystems).

Understanding the Standard

This standard extends the study of ecosystems to the ocean environment. It focuses on the major descriptive characteristics of oceans. Among the concepts are the geological characteristics of the ocean floor, the physical characteristics of ocean water, and the ecological characteristics of communities of marine organisms. Connections can be made to standards 5.2, 5.3, 5.4, 5.5, and 5.7. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

Standard 5.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Oceans cover about 70percent of the surface of the Earth.• Important features of the ocean floor near the continents are the continental shelf, the continental slope, and the continental rise. These areas are covered with thick layers of sediments (sand, mud, rocks).• The depth of the ocean varies. Ocean trenches are very deep, and the continental shelf is relatively shallow.• Ocean water is a complex mixture of gases (air) and dissolved solids (salts, especially sodium chloride). Marine organisms are dependent on dissolved gases for survival. The salinity of ocean water varies in some places depending on rates of evaporation and amount of runoff from nearby land.• The <i>basic motions</i> of ocean water are the waves, currents, and tides.• Ocean currents, including the Gulf Stream, are caused by wind patterns and the differences in water densities (due to salinity and temperature differences). Ocean currents affect the mixing of ocean waters. This can affect plant and animal populations. Currents also affect navigation routes.• As the depth of ocean water increases, the temperature decreases, the pressure increases, and the amount of light decreases. These factors influence the type of life forms that are present at a given depth.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain key terminology related to the ocean environment.• create and interpret a model of the ocean floor and label and describe each of the major features.• research and describe the variation in depths associated with ocean features, including the continental shelf, slope, rise, the abyssal plain, and ocean trenches.• design an investigation (including models and simulations) related to physical characteristics of the ocean environment (depth, salinity, formation of waves, and currents, such as the Gulf Stream).• interpret graphical data related to physical characteristics of the ocean.• explain the formation of ocean currents and describe and locate the Gulf Stream.• design an investigation (including models and simulations) related to biologic characteristics of the ocean environment (ecological relationships).• interpret graphical data related to the biological characteristics of the ocean, such as the number of organisms vs. the depth of the water.

Standard 5.6 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Plant-like plankton (phytoplankton) produce much of the Earth's oxygen and serve as the base of the ocean ecosystem. Plankton flourish in areas where nutrient-rich water upwells from the deep. Phytoplankton are eaten by animal-like plankton, swimming organisms, and those things that live on the ocean bottom.	<ul style="list-style-type: none">• analyze how the physical characteristics (depth, salinity, and temperature) of the ocean affect where marine organism can live.• create and interpret a model of a basic marine food web, including floating organisms (plankton), swimming organisms, and organisms living on the ocean bottom.

Grade Five Science Strand

Earth Patterns, Cycles, and Change

This strand focuses on student understanding of patterns in nature, natural cycles, and changes that occur both quickly and slowly over time. An important idea represented in this strand is the relationship among Earth patterns, cycles, and change and their effects on living things. The topics developed include noting and measuring changes, weather and seasonal changes, the water cycle, cycles in the Earth-moon-sun system, and change in the Earth's surface over time. This strand includes science standards K.8, K.9, 1.7, 2.7, 3.8, 3.9, 4.7, and 5.7.

Strand: Earth Patterns, Cycles, and Change

Standard 5.7

The student will investigate and understand how the Earth's surface is constantly changing. Key concepts include

- a) the rock cycle including identification of rock types;
- b) Earth history and fossil evidence;
- c) the basic structure of the Earth's interior;
- d) plate tectonics (earthquakes and volcanoes);
- e) weathering and erosion; and
- f) human impact.

Understanding the Standard

This standard focuses on the constantly changing nature of the Earth's surface and builds on concepts learned in standards 4.6 and 4.8. Among the important ideas presented in this standard are the rock cycle, fossil evidence of change over time, energy from within the Earth that drives tectonic plate movement, shifting tectonic plates that cause earthquakes and volcanoes, weathering and erosion, and human interaction with the Earth's surface. This standard can be related to several ideas found in science standard 5.6. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (5.1) in the context of the key concepts presented in this standard.

Standard 5.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none"> • Rocks move and change over time due to heat and pressure within the Earth and to <i>weathering</i> and <i>erosion</i> at the surface. These and other processes constantly change rock from one type to another. • Rocks have properties that can be observed, tested, and described. Composition, grain size and textural features, color, and the presence of fossils help with identification. Classification keys (5.1) can aid this process. • Depending on how rocks are formed, they are classified as <i>sedimentary</i> (layers of sediment cemented together), <i>igneous</i> (melted and cooled, e.g., lava and magma), and <i>metamorphic</i> (changed by heat and pressure). • Scientific evidence indicates the Earth is very ancient — approximately 4.6 billion years old. The age of many rocks can be determined very reliably. Fossils provide information about life and conditions of the past. • Scientific evidence indicates that the Earth is composed of four concentric layers — crust, mantle, inner core, and outer core — each with its own distinct characteristics. The outer two layers are composed primarily of rocky material. The innermost layers are composed mostly of iron and nickel. Pressure and temperature increase with depth beneath the surface. 	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none"> • apply basic terminology (<i>italic print in overview</i>) to explain how the Earth surface is constantly changing. • draw and label the rock cycle and describe the major processes and rock types involved. • compare and contrast the origin of igneous, sedimentary, and metamorphic rocks. • identify rock samples (granite, gneiss, slate, limestone, shale, sandstone, and coal), using a rock classification key. • make plausible inferences about changes in the Earth over time based on fossil evidence. This includes the presence of fossils of organisms in sedimentary rocks of Virginia found in the Appalachians, Piedmont, and Coastal Plain/Tidewater. • describe the structure of Earth in terms of its major layers — crust, mantle, and inner and outer cores — and how the Earth’s interior affects the surface. • differentiate among the three types of plate tectonic boundaries (divergent, convergent, and sliding) and how these relate to the changing surface of the Earth and the ocean floor (5.6).

Standard 5.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• The Earth's heat energy causes movement of material within the Earth. Large continent-size blocks (plates) move slowly about the Earth's surface, driven by that heat.• Most earthquakes and volcanoes are located at the boundary of the plates (faults). Plates can move together (convergent boundaries), apart (divergent boundaries), or slip past each other horizontally (sliding boundaries, also called strike-slip or transform boundaries).• Geological features in the oceans (including trenches and mid-ocean ridges) and on the continents (mountain ranges, including the Appalachian Mountains) are caused by current and past plate movements.• Rocks and other materials on the Earth's surface are constantly being broken down both chemically and physically. The products of weathering include clay, sand, rock fragments, and soluble substances. Weathered rock material can be moved by water and wind and deposited as sediment.• Humans have varying degrees of impact on the Earth's surface through their everyday activities. With careful planning, the impact on the land can be controlled.	<ul style="list-style-type: none">• compare and contrast the origin of earthquakes and volcanoes and how they affect the Earth's surface.• design an investigation to locate, chart, and report weathering and erosion at home and on the school grounds. Create a plan to solve erosion problems that may be found.• differentiate between weathering and erosion.• design an investigation to determine the amount and kinds of weathered rock material found in soil.• describe how people change the Earth's surface and how negative changes can be controlled.



Science Standards of Learning Curriculum Framework

Grade Six

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Grade Six Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of inquiry skills that defines what a student should be able to do when conducting activities and investigations. The various skill categories are described in the “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*, and the skills in science standards 6.1 represent more specifically what a student should be able to do as a result of science experiences in sixth grade. Across the grade levels, the skills in the “Scientific Investigation, Reasoning, and Logic” strand form a nearly continuous sequence of investigative skills. (Please note Appendix, “Science Skills, Scope, & Sequence.”) It is important that the classroom teacher understands how the skills in standard 6.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, and 5.1). The sixth grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed.

Strand: Scientific Investigation, Reasoning, and Logic

Standard 6.1

The student will plan and conduct investigations in which

- a) observations are made involving fine discrimination between similar objects and organisms;
- b) a classification system is developed based on multiple attributes;
- c) precise and approximate measurements are recorded;
- d) scale models are used to estimate distance, volume, and quantity;
- e) hypotheses are stated in ways that identify the independent (manipulated) and dependent (responding) variables;
- f) a method is devised to test the validity of predictions and inferences;
- g) one variable is manipulated over time, using many repeated trials;
- h) data are collected, recorded, analyzed, and reported using appropriate metric measurements;
- i) data are organized and communicated through graphical representation (graphs, charts, and diagrams);
- j) models are designed to explain a sequence; and
- k) an understanding of the nature of science is developed and reinforced.

Understanding the Standard

The skills described in standard 6.1 are intended to define the “investigate” component of all of the other sixth grade standards (6.2–6.9). The intent of standard 6.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed at the sixth grade. Standard 6.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other sixth grade standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science, as well as more fully grasp the content-related concepts in the standards.

Standard 6.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• To communicate an observation accurately, one must provide critical details of exactly what is being observed. Using that information, students will be able to differentiate definitively between or among similar objects and/or organisms.• In an effective classification system, accurate comparisons and contrasts are made.• Systematic investigations require accurate measurements; however, in the absence of precision tools, observers must record careful estimations.• Scale models must maintain relative values of size and/or quantity in order to maintain the integrity of the object or topic being modeled.• An <i>experiment</i> is a structured test of a hypothesis. A <i>hypothesis</i> is stated in terms of a testable relationship.• A scientific <i>prediction</i> is a forecast about what may happen in some future situation. It is based on the application of scientific principle and factual information. An <i>inference</i> is a conclusion based on evidence about events that have already occurred.• Accurate observations and evidence are necessary to draw realistic and plausible conclusions.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• make observations that can be used to discriminate similar objects and organisms, paying attention to fine detail.• develop a classification key that uses numerous characteristics.• make precise and consistent measurements and estimations.• create approximate scale models to demonstrate an understanding of distance, volume, and quantity.• differentiate between independent (manipulated) and dependent (responding) variables in a hypothesis.• compare and contrast predictions and inferences. Analyze and judge the evidence, observations, scientific principles, and data used in making predictions and inferences.• design an experiment in which one variable is manipulated over many trials.• collect, record, analyze, and report data, using metric terminology.• organize and communicate data, using graphs (bar, line, and circle), charts, and diagrams.• design a model that explains a sequence, for example, the sequence of events involved in the process of photosynthesis.

Standard 6.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• In order to conduct an experiment, one must recognize all of the potential variables that can affect an outcome.• In a scientific investigation, data should be collected, recorded, analyzed, and reported using appropriate metric measurement.• In a scientific investigation, data should be organized and communicated through appropriate graphical representation (graph, chart, table, and diagram).• Models provide a way of visually representing abstract concepts. The use of models permits students to order events or processes.• Patterns discerned from direct observations can be the basis for predictions or hypotheses that attempt to explain the mechanism responsible for the pattern.	<ul style="list-style-type: none">• propose hypotheses or predictions from observed patterns.

Grade Six Science Strand

Force, Motion, and Energy

The strand focuses on student understanding of what force, motion, and energy are and how the concepts are connected. The major topics developed in this strand include magnetism; types of motion; simple machines; and energy forms and transformations, especially electricity, sound, and light. This strand includes science standards K.3, 1.2, 2.2, 3.2, 4.2, 4.3, 5.2, 5.3, 6.2, and 6.3.

Strand: Force, Motion, and Energy

Standard 6.2

The student will investigate and understand basic sources of energy, their origins, transformations, and uses. Key concepts include

- a) potential and kinetic energy;
- b) the role of the sun in the formation of most energy sources on Earth;
- c) nonrenewable energy sources (fossil fuels, including petroleum, natural gas, and coal);
- d) renewable energy sources (wood, wind, hydro, geothermal, tidal, and solar); and
- e) energy transformations (heat/light to mechanical, chemical, and electrical energy).

Understanding the Standard

Most sources of energy on the Earth are the result of solar radiation, either energy the Earth is currently receiving or energy that has been stored as fossil fuels. Heat energy also comes from the Earth's interior. All energy exists in two basic forms, — kinetic and potential. Understanding the forms of energy and their transformations will provide the foundation for students to investigate the transfer of energy within living and Earth systems as well as to understand chemical reactions, force, and motion. This standard builds upon concepts of energy sources introduced in science standard 3.11. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• <i>Potential energy</i> is energy that is not “in use” and available to do work. <i>Kinetic energy</i> is energy that is “in use” — the energy a moving object has due to its motion. For example, moving water and wind have kinetic energy. The chemical energy in fossil fuels is potential energy until it is released.• Some important sources of energy include fossil fuels, wood, wind, water (hydropower), the sun (solar energy), and the Earth’s interior.• Heat and light can be converted into mechanical energy, chemical energy, and electrical energy and back again.• Solar energy from the ancient past is stored in fossil fuels, such as coal and petroleum. Fossil fuels are rich in the elements carbon and hydrogen. These sources of energy take very long periods of time to form and once depleted, are essentially nonrenewable.• Many of the Earth’s energy resources are available on a perpetual basis. These include solar, wind, water, and geothermal energy. Some energy sources can be replenished over relatively short periods of time. These include wood and other biomass. All are considered renewable.• Modern industrial society is dependent upon energy. Fossil fuels are the major sources of energy in developed and industrialized nations.	<p>In order to meet this standard, it is expected that students should be able</p> <ul style="list-style-type: none">• comprehend and apply basic terminology related to energy sources and transformations.• compare and contrast potential and kinetic energy through common examples found in the natural environment.• create and interpret a model or diagram of an energy transformation.• analyze and describe the transformations of energy involved with the formation and burning of coal and other fossil fuels.• compare and contrast renewable and nonrenewable energy sources.• design an investigation that demonstrates light energy being transformed into other forms of energy.• design an application of the use of solar and wind energy.• chart and analyze the energy a person uses during a 24-hour period and determine the sources.• compare and contrast energy sources in terms of their origins, how they are utilized, and their availability.• analyze the advantages and disadvantages of using various energy sources.

Standard 6.2 (continued)

Overview	Essential Knowledge, Skills, and Processes
	<ul style="list-style-type: none">• analyze and describe how the United States’ energy use has changed over time.• predict the impact of unanticipated energy shortages.

Strand: Force, Motion, and Energy

Standard 6.3

The student will investigate and understand the role of solar energy in driving most natural processes within the atmosphere, the hydrosphere, and on the Earth's surface. Key concepts include

- a) the Earth's energy budget;
- b) the role of radiation and convection in the distribution of energy;
- c) the motion of the atmosphere and the oceans;
- d) cloud formation; and
- e) the role of heat energy in weather-related phenomena including thunderstorms and hurricanes.

Understanding the Standard

The key concepts defined in this standard are intended to expand student understanding of the effects of solar radiation entering the Earth's atmosphere on weather and ocean current patterns. The distribution of energy through convection and radiation are explored as students study cloud formation and movement patterns of the atmosphere and the world's oceans. This standard is closely related to standards 6.2 and 6.6 and builds on the weather concepts developed in standard 4.6 and concepts of visible light in standard 5.3. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The Earth receives only a very small portion of the sun's energy, yet this energy is responsible for powering the motion of the atmosphere, the oceans, and many processes at the Earth's surface.• Solar radiation is made up of different types of radiation (including infrared, visible light, and ultraviolet).• Incoming solar radiation is in close balance with the energy that leaves the atmosphere; otherwise the Earth would heat up or cool down. Excess carbon dioxide and other gases may disrupt this balance, creating a Greenhouse Effect.• About one third of the sun's incoming energy is reflected back out to space. About one half of the energy striking the Earth is absorbed by the Earth's surface.• The Earth's surface is heated unequally.• When air or water is heated, the molecules move faster and farther apart, reducing their density and causing them to rise. Cooler air or water molecules move more slowly and are denser than warm air or water. Warm air or water rising coupled with cooler air or water descending forms a cyclic rising/falling pattern called <i>convection</i>.• Radiation and convection from the Earth's surface transfer heat energy. This energy powers the global circulation of the atmosphere and the oceans on our planet.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• comprehend and apply basic terminology related to solar energy, including <i>wavelength</i>; <i>ultraviolet</i>, <i>visible</i>, and <i>infrared radiation</i>; and <i>reflection</i> and <i>absorption</i>.• analyze and interpret a chart or diagram showing the Earth's energy budget.• analyze, model, and explain the Greenhouse Effect in terms of the energy entering and leaving the atmosphere.• design an investigation to determine the effect of sunlight on the heating of a surface.• analyze the role of heating and cooling in the formation of clouds.• order the sequence of events that takes place in the formation of a cloud.• analyze and explain how convection currents occur and how they distribute heat energy in the atmosphere and oceans.

Standard 6.3 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• As bodies of water (oceans, lakes, rivers, etc.) absorb heat energy, the water evaporates forming clouds.• Warm, moist air is less dense than cold, dry air, so it rises relative to colder, drier air. As warm, moist air rises, it actually gives off some heat as the moisture condenses. Clouds are not gaseous water vapor; rather they are minute, condensed water particles.• Some thunderstorms are formed where the land is strongly heated. Hurricanes form over warm, tropical water and are fed by the energy of that water.	

Grade Six Science Strand

Matter

This strand focuses on the description, physical properties, and basic structure of matter. The major topics developed in this strand include concepts related to the basic description of objects, states of matter (solids, liquids, and gases – especially water), phase changes, mass and volume, and the structure of classification of matter. This strand includes science standards K.4, K.5, 1.3, 2.3, 3.3, 5.4, 6.4, 6.5, and 6.6.

Standard 6.4

The student will investigate and understand that all matter is made up of atoms. Key concepts include

- a) atoms are made up of electrons, protons, and neutrons;
- b) atoms of any element are alike but are different from atoms of other elements;
- c) elements may be represented by chemical symbols;
- d) two or more atoms may be chemically combined;
- e) compounds may be represented by chemical formulas;
- f) chemical equations can be used to model chemical changes; and
- g) a limited number of elements comprise the largest portion of the solid Earth, living matter, the oceans, and the atmosphere.

Understanding the Standard

Standard 6.4 focuses on an understanding of the basic structure of the atom, including electrons, protons, and neutrons. The concepts defined in standard 6.4 build on students' basic understanding of the structure of matter as introduced in science standards 3.3 and 5.4. Knowledge of basic chemistry concepts is fundamental to understanding the physical sciences, life processes, and Earth and environmental science ideas. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The basic structural components of the typical atom are <i>electrons</i>, <i>protons</i>, and <i>neutrons</i>. Protons and neutrons comprise the <i>nucleus</i> of an atom.• An <i>element</i> is a form of matter made up of one type of atom. The atoms of an element are basically alike, though the number of neutrons may vary.• The atoms of one element differ from those of another element in the number of protons.• Elements can be represented by chemical symbols.• Two or more atoms of different elements may combine to form a <i>compound</i>.• Compounds can be represented by chemical formulas. Each different element in the compound is represented by its unique symbol. The number of each type of element in the compound (other than 1) is represented by a small number (the subscript) to the right of the element symbol.• Chemical equations can be used to model chemical changes, illustrating how elements become rearranged in a chemical reaction.• A limited number of elements, including silicon, aluminum, iron, sodium, calcium, potassium, magnesium, hydrogen, oxygen, nitrogen, and carbon, form the largest portion of the Earth's crust, living matter, the oceans, and the atmosphere.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• create and interpret a simplified model of the structure of an atom.• compare and contrast the atomic structure of two different elements.• explain that elements are represented by symbols.• identify the name and number of each element present in a simple molecule or compound, such as O₂, H₂O, CO₂, or CaCO₃.• model a simple chemical change with an equation and account for all atoms. Distinguish the types of elements and number of each element in the chemical equation. (Balancing equations will be further developed in Physical Science).• name some of the predominant elements found in the atmosphere, the oceans, living matter, and the Earth's crust.

Standard 6.5

The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include

- a) water as the universal solvent;
- b) the properties of water in all three states;
- c) the action of water in physical and chemical weathering;
- d) the ability of large bodies of water to store heat and moderate climate;
- e) the origin and occurrence of water on Earth;
- f) the importance of water for agriculture, power generation, and public health; and
- g) the importance of protecting and maintaining water resources.

Understanding the Standard

Standard 6.5 is intended to develop student understanding of the unique properties of water and the importance of protecting and managing water resources. Understanding the structure, properties, and behavior of the water molecule is fundamental to understanding more complex environmental systems. Concepts like solubility, surface tension, cohesion, adhesion, density, condensation, and evaporation can be investigated to appreciate why the properties of water are critical to life processes and living things. This standard also introduces the concept of the ability of large bodies of water to moderate the climate on land. The connections between water resources and agriculture, power generation, and public health are also investigated. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Water is the only compound that commonly exists in all three states (solid, liquid, gas) on Earth. The unique properties of water are a major factor in the ability of our planet to sustain life.• Among water's unique properties is that one side of each water molecule is slightly negative and the other is slightly positive. Individual water molecules, therefore, attract other water molecules like little magnets as the slightly positive portion of a water molecule is attracted to the slightly negative portion of an adjacent water molecule. In this way, water molecules "stick together."• A large number of substances will "dissolve" in water. For this reason, water is often called the universal solvent.• Water is able to absorb heat energy without showing relatively large changes in temperature. Large bodies of water act to moderate the climate of surrounding areas by absorbing heat in summer and slowly releasing that heat in the winter. For this reason, the climate near large bodies of water is slightly milder than areas without large bodies of water.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• comprehend and apply key terminology related to water and its properties and uses.• model and explain the shape and composition of a water molecule.• design an investigation to determine the relative density of liquid and solid water at various temperatures.• compare the relative densities of liquid and solid water.• comprehend the adhesive and cohesive properties of water.• design an investigation to determine the effects of heat on the states of water.• model and explain why ice is less dense than liquid water.• relate the three states of water to the water cycle.• design an investigation to demonstrate the ability of water to dissolve materials.• design an investigation to determine the presence of water in plant material (e.g., a fruit).• infer how the unique properties of water are key to the life processes of organisms.

Standard 6.5 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Additional properties of water are its high surface tension and the large range of temperature (0–100 degrees Celsius) in which it can be found in the liquid state, as well as the fact that, unlike other substances, it expands when it freezes. Ice is less dense than liquid water.• Water (rain, ice, snow) has shaped our environment by physically and chemically weathering rock and soil and transporting sediments. Freezing water can break rock without any change in the minerals that form the rock (physical weathering). This usually produces small particles and sand. Water with dissolved gases and other chemicals causes the minerals in rocks to be changed, leading to the deterioration of the rock (chemical weathering).• Scientific evidence indicates that the Earth formed about four-and-a-half billion years ago from the dust and debris orbiting the sun. Due to gravity, this debris became compacted and grew quite hot, creating hot gases, including water vapor and carbon dioxide. Over millions of years, the Earth and its gases cooled, and seas are believed to have formed when the Earth cooled enough for water vapor in the atmosphere to condense.• Most of Earth’s water is salt water in the oceans (97 percent). Available non-frozen, fresh water makes up less than 1 percent of the water on Earth.	<ul style="list-style-type: none">• design an investigation to model the action of freezing water on rock material.• design an investigation to model the action of acidified water on building materials such as concrete, limestone, or marble.• chart, record, and describe evidence of chemical weathering in the local environment.• explain the role of water in power generation.• analyze and explain the difference in average winter temperatures among areas in central and western Virginia and cities and counties along the Chesapeake Bay and Atlantic coast.• describe the importance of careful management of water resources.

Standard 6.5 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Water occurs on Earth in oceans, lakes, rivers, streams, and in rock layers underground called aquifers. A large amount of water is also found in the bodies of living things.• The first human settlements were established near springs, rivers, and lakes. Reliable fresh water sources and irrigation systems allowed civilizations to grow and flourish. As cities grew, different strategies (tunnels, aqueducts, wells, cisterns, pumps, reservoirs) were employed to collect water..• Water is essential for agriculture. Crops watered by reliable irrigation systems are more productive, and harvests more dependable.• Water is an important resource used in power generation. Hydroelectric power plants make use of the kinetic energy of water as it flows through turbines. Water is also heated in power plants and turned to steam. The steam is used to turn turbines, which generate electricity.• In the past, streams and rivers were often used to dispose of human waste, and open sewers were common. During the mid-1800s, public health officials recognized the connection between disease outbreaks and contamination of public wells and drinking water. Advances in water treatment and sanitary sewers have helped eliminate diseases associated with human waste.	

Standard 6.6

The student will investigate and understand the properties of air and the structure and dynamics of the Earth's atmosphere. Key concepts include

- a) air as a mixture of gaseous elements and compounds;
- b) air pressure, temperature, and humidity;
- c) how the atmosphere changes with altitude;
- d) natural and human-caused changes to the atmosphere;
- e) the relationship of atmospheric measures and weather conditions;
- f) basic information from weather maps including fronts, systems, and basic measurements; and
- g) the importance of protecting and maintaining air quality.

Understanding the Standard

Standard 6.6 is intended to provide students with a basic understanding of the properties of air, the structure of the atmosphere, weather, and air quality. Students need to understand there are both natural and human-caused changes to the atmosphere and that the results of these changes are not yet fully understood. A basic understanding of weather and weather prediction builds on the key concepts in standard 4.6. Standard 6.6 also focuses on student understanding of air quality as an important parameter of human and environmental health. It is important to make the obvious connections between this standard and the other sixth grade standards. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Air is a mixture of gaseous elements and compounds. These include nitrogen, oxygen, water, argon and carbon dioxide. Nitrogen makes up the largest proportion of air.• Air exerts pressure. Air pressure decreases as altitude increases.• Moisture in the air is called <i>humidity</i>.• The atmosphere is made up of layers (troposphere, stratosphere, mesosphere, and thermosphere) that have distinct characteristics.• Temperature decreases as altitude increases in the lowest layer of the atmosphere.• Most of the air that makes up the atmosphere is found in the troposphere(the lowest layer). Virtually all weather takes place there.• Forest fires and volcanic eruptions are two natural processes that affect the Earth's atmosphere. Many gaseous compounds and particles are released into the atmosphere by human activity. All of the effects of these materials are not yet fully understood.• The amounts of heat energy and water vapor in the air and the pressure of the air largely determine what the weather conditions are.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• comprehend and apply basic terminology related to air and the atmosphere.• identify the composition and physical characteristics of the atmosphere.• analyze and interpret charts and graphs of the atmosphere in terms of temperature and pressure.• measure and record air temperature, air pressure, and humidity, using appropriate units of measurement and tools.• analyze and explain some of the effects that natural events and human activities may have on weather, atmosphere, and climate.• map the movement of cold and warm fronts and interpret their effects on observable weather conditions.• design an investigation to relate temperature, barometric pressure, and humidity to changing weather conditions.• interpret basic weather maps and make forecasts based on the information presented.• compare and contrast cloud types and relate cloud types to weather conditions.

Standard 6.6 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Weather maps show much useful information about descriptive air measurements, observations, and boundaries between air masses (fronts). The curved lines showing areas of equal air pressure and temperature are key features of weather maps. Weather maps are important for understanding and predicting the weather.• Clouds are important indicators of atmospheric conditions. Clouds are found at various levels within the troposphere. Three major types of clouds are cumulus, stratus, and cirrus.• <i>Ozone</i>, a form of oxygen, can form near the surface when exhaust pollutants react with sunlight. This pollutant can cause health problems. Naturally occurring ozone is also found in the upper atmosphere and helps to shield the Earth from ultraviolet radiation.• Maintaining good air quality is a crucial goal for modern society, and it is everyone's responsibility to work toward it.	<ul style="list-style-type: none">• compare and contrast types of precipitation.• compare and contrast weather-related phenomena, including thunderstorms, tornadoes, hurricanes, and drought.• evaluate their own roles in protecting air quality.

Grade Six Science Strand

Living Systems

The strand begins in second grade and builds from basic to more complex understandings of a system, both at the ecosystem level and at the level of the cell. The concept of kingdoms of organisms and a general classification of organisms are also presented. The other major topics developed in the strand include the types of relationships among organisms in a food chain, different types of environments and the organisms they support, and the relationship between organisms and their nonliving environment. This strand includes science standards 2.5, 3.5, 3.6, 4.5, 5.5, and 6.7.

Strand: Living Systems

Standard 6.7

The student will investigate and understand the natural processes and human interactions that affect watershed systems. Key concepts include

- a) the health of ecosystems and the abiotic factors of a watershed;
- b) the location and structure of Virginia's regional watershed systems;
- c) divides, tributaries, river systems, and river and stream processes;
- d) wetlands;
- e) estuaries;
- f) major conservation, health, and safety issues associated with watersheds; and
- g) water monitoring and analysis using field equipment including hand-held technology.

Understanding the Standard

Standard 6.7 is intended to provide students with a basic understanding of how natural processes and human interactions impact watershed systems. This includes an understanding of the physical geography of Virginia's portions of the three major watershed systems (the Chesapeake Bay, the North Carolina sounds, and the Gulf of Mexico) and the various features associated with moving water (surface and groundwater). Wetlands have become an important focus of scientists as we learn their role in flood and erosion control as well as their importance as habitat for many species of living things. Students are introduced to major safety and conservation issues associated with watersheds and become familiar with the testing parameters and tools used in the field. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• An ecosystem is made up of the living community and the nonliving factors that affect it. The health of an ecosystem is directly related to water quality.• Abiotic factors determine ecosystem type and its distribution of plants and animals as well as the usage of land by people. Abiotic factors include water supply, topography, landforms, geology, soils, sunlight, and air quality/O₂ availability.• Human activities can alter abiotic components and thus accelerate or decelerate natural processes. For example, people can affect the rate of natural erosion. Plowing cropland can cause greater erosion, while planting trees can prevent it. Flood protection/wetland loss is another example.• A <i>watershed</i> is the land that water flows across or through on its way to a stream, lake, wetland, or other body of water. Areas of higher elevations, such as ridgelines and divides, separate watersheds.• The three major regional watersheds systems in Virginia lead to the Chesapeake Bay, the North Carolina sounds, or the Gulf of Mexico.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• comprehend and apply basic terminology related to watersheds.• use topographic maps to determine the location and size of Virginia's regional watershed systems.• locate their own local watershed and the rivers and streams associated with it.• design an investigation to model the effects of stream flow on various slopes.• analyze and explain the functioning of wetlands and appraise the value of wetlands to humans.• describe an example of a wetland.• explain what an estuary is and why it is important to people.• propose ways to maintain water quality within a watershed.• explain the factors that affect water quality in a watershed and how those factors can affect an ecosystem.• forecast potential water-related issues that may become important in the future.

Standard 6.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• River systems are made up of tributaries of smaller streams that join along their courses. Rivers and streams generally have wide, flat, border areas, called flood plains, onto which water spills out at times of high flow.• Rivers and streams carry and deposit sediment. As water flow decreases in speed, the size of the sediment it carries decreases.• Wetlands form the transition zone between dry land and bodies of water such as rivers, lakes, or bays. Both tidal and non-tidal wetlands perform important water quality functions, including regulating runoff by storing flood waters; reducing erosion by slowing down runoff; maintaining water quality by filtering sediments, trapping nutrients, and breaking down pollutants; and recharging groundwater. They also provide food and shelter for wildlife and fish and nesting and resting areas for migratory birds.• Estuaries perform important functions, such as providing habitat for many organisms and serving as nurseries for their young.• The Chesapeake Bay is an estuary where fresh and salt water meet and are mixed by tides. It is the largest estuary in the contiguous United States and one of the most productive.• Water quality monitoring is the collection of water samples to analyze chemical and/or biological parameters. Simple parameters include pH, temperature, salinity, dissolved oxygen, turbidity, and the presence of macroinvertebrate organisms.	<ul style="list-style-type: none">• locate and critique a media article or editorial (print or electronic) concerning water use or water quality. Analyze and evaluate the science concepts involved.• argue for and against commercially developing a parcel of land containing a large wetland area. Design and defend a land-use model that minimizes negative impact.• measure, record, and analyze a variety of water quality indicators and describe what they mean.

Grade Six Science Strand

Interrelationships in Earth/Space Systems

The strand focuses on student understanding of how Earth systems are connected and how the Earth interacts with other members of the solar system. The topics developed include shadows; relationships between the sun and the Earth; weather types, patterns, and instruments; properties of soil; characteristics of the ocean environment; and organization of the solar system. This strand includes science standards K.7, 1.6, 2.6, 3.7, 4.6, 5.6, and 6.8.

Strand: Interrelationships in Earth/Space Systems

Standard 6.8

The student will investigate and understand the organization of the solar system and the relationships among the various bodies that comprise it. Key concepts include

- a) the sun, moon, Earth, other planets and their moons, meteors, asteroids, and comets;
- b) relative size of and distance between planets;
- c) the role of gravity;
- d) revolution and rotation;
- e) the mechanics of day and night and the phases of the moon;
- f) the unique properties of Earth as a planet;
- g) the relationship of the Earth's tilt and the seasons;
- h) the cause of tides; and
- i) the history and technology of space exploration.

Understanding the Standard

Standard 6.8 is intended to provide students with a basic understanding of the solar system, how it is organized, and the relationships among bodies within the solar system. This standard develops an understanding of the Earth as part of the solar system and builds significantly on standards 3.8 and 4.7. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The solar system consists of the sun, moon, Earth, other planets and their moons, meteors, asteroids, and comets. Each body has its own characteristics and features.• The distance between planets and sizes of the planets varies greatly. The outer, “gas” planets are very large, and the four inner planets are comparatively small and rocky.• Gravity is a force that keeps the planets in motion around the sun. Gravity acts everywhere in the universe.• Planets revolve around the sun, and moons revolve around planets. A planet rotates upon an axis.• As the Earth rotates, different sides of the Earth face toward or away from the sun, thus causing day and night, respectively.• The phases of the moon are caused by its position relative to the Earth and sun.• The Earth is a rocky planet, extensively covered with large oceans of liquid water and having frozen ice caps in its polar regions. The Earth has a protective atmosphere consisting predominantly of nitrogen and oxygen and has a magnetic field. The atmosphere and the magnetic field help shield the Earth’s surface from harmful solar radiation. Scientific evidence indicates that the Earth is about 4.5 billion years old.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe the nine planets and their relative positions from the sun.• design and interpret a scale model of the solar system. (A scale model may be a physical representation of an object or concept. It can also be a mathematical representation that uses factors such as ratios, proportions, and percentages.)• explain the role of gravity in the solar system.• compare and contrast revolution and rotation and apply these terms to the relative movements of planets and moons their moons.• model and describe how day and night and the phases of the moon occur.• model and describe how the Earth’s axial tilt and its annual orbit around the sun cause the seasons.• describe the unique characteristics of planet Earth.• discuss the relationship between the gravitational pull of the moon and the cycle of tides.• compare and contrast the ideas of Ptolemy, Aristotle, Copernicus, and Galileo related to the solar system.

Standard 6.8 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Seasons are caused by the tilt of the Earth on its axis and, thus, the angle at which sunlight strikes the surface of the Earth during its annual revolution around the sun.• Tides are the result of the gravitational pull of the moon and sun on the surface waters of the Earth.• The ideas of Ptolemy, Aristotle, Copernicus, and Galileo contributed to the development of our understanding of the solar system.• With the development of new technology over the last half-century, our knowledge of the solar system has increased substantially.	<ul style="list-style-type: none">• create and interpret a timeline highlighting the advancements in solar system exploration over the past half century. This should include information on the first modern rockets, artificial satellites, orbital missions, missions to the moon, Mars robotic explorers, and exploration of the outer planets.

Grade Six Science Strand

Resources

The strand focuses on student understanding of the role of resources in the natural world and how people can utilize those resources in a sustainable way. An important idea represented in this strand is the concept of management of resource use. This begins with basic ideas of conservation and proceeds to more abstract consideration of costs and benefits. The topics developed include conservation of materials, soil and plants as resources, energy use, water, Virginia's resources, and how public policy impacts the environment. This strand includes science standards K.10, 1.8, 2.8, 3.10, 3.11, 4.8, and 6.9.

Standard 6.9

The student will investigate and understand public policy decisions relating to the environment. Key concepts include

- a) management of renewable resources (water, air, soil, plant life, animal life);
- b) management of nonrenewable resources (coal, oil, natural gas, nuclear power, mineral resources);
- c) the mitigation of land-use and environmental hazards through preventive measures; and
- d) cost/benefit tradeoffs in conservation policies.

Understanding the Standard

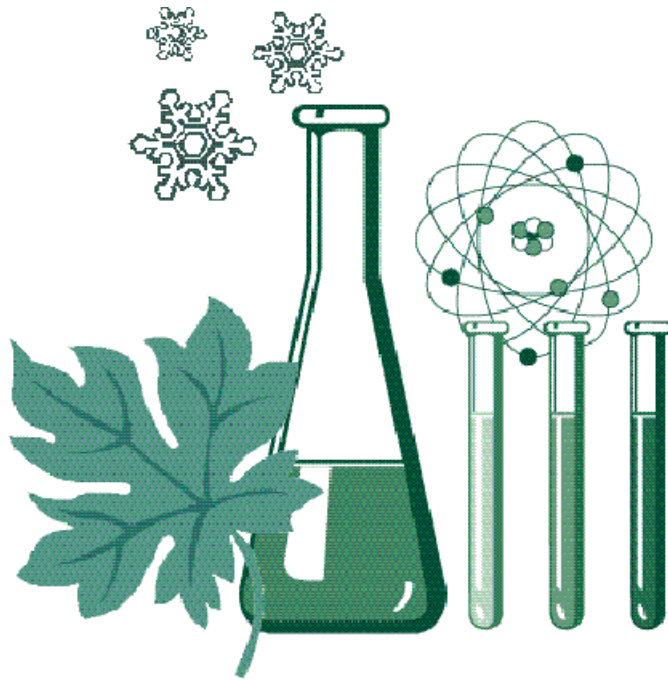
Standard 6.9 is intended to develop student understanding of the importance of the Earth's natural resources, the need to manage them, how they are managed, and the analysis of costs and benefits in making decisions about those resources. It applies and builds on the concepts described in several lower grades, especially science standard 4.8. Knowledge gained from this standard will be important to understanding numerous concepts in Life Science and Earth Science. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (6.1) in the context of the key concepts presented in this standard.

Standard 6.9

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• People, as well as other living organisms, are dependent upon the availability of clean water and air and a healthy environment.• Local, state, and federal governments have significant roles in managing and protecting air, water, plant, and wildlife resources.• Modern society is dependent upon many finite resources, including coal, oil, natural gas, and nuclear power.• Many renewable and nonrenewable resources are managed by the private sector (private individuals and corporations).• Regulations, incentives, and voluntary efforts help conserve resources and protect environmental quality.• Conservation of resources and environmental protection begin with the individual.• Use of renewable and nonrenewable resources must be considered in terms of their cost/benefit tradeoffs.• Preventive measures, such as pollution prevention or thoughtfully planned and enforced land-use restrictions, can reduce the impact of potential problems in the future.• Pollution prevention and waste management are less costly than cleanup.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• differentiate between renewable and nonrenewable resources.• describe the role of local and state conservation professionals in managing natural resources. These include wildlife protection; forestry and waste management; and air, water, and soil conservation.• analyze resource-use options in everyday activities and determine how personal choices have costs and benefits related to the generation of waste.• analyze how renewable and nonrenewable resources are used and managed within the home, school, and community.• analyze reports, media articles, and other narrative materials related to waste management and resource use to determine various perspectives concerning the costs/benefits in real-life situations.• evaluate the impact of resource use, waste management, and pollution prevention in the school and home environment.

Standard 6.9 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Renewable resources should be managed so that they produce continuously. Sustainable development makes decisions about long-term use of the land and natural resources for maximum community benefit for the longest time and with the least environmental damage.	



Science Standards of Learning Curriculum Framework

Life Science

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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Standard LS.1

The student will plan and conduct investigations in which

- a) data are organized into tables showing repeated trials and means;
- b) variables are defined;
- c) metric units (SI — International System of Units) are used;
- d) models are constructed to illustrate and explain phenomena;
- e) sources of experimental error are identified;
- f) dependent variables, independent variables, and constants are identified;
- g) variables are controlled to test hypotheses, and trials are repeated;
- h) continuous line graphs are constructed, interpreted, and used to make predictions;
- i) interpretations from a set of data are evaluated and defended; and
- j) an understanding of the nature of science is developed and reinforced.

Understanding the Standard

The skills described in standard LS.1 are intended to define the “investigate” component of all of the other Life Science standards (LS.2–LS.14). The intent of standard LS.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed in the Life Science course. This does not preclude explicit instruction on a particular inquiry skill or skills, but standard LS.1 does not require a discrete unit on scientific investigation. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science, as well as more fully grasp the content-related concepts.

Across the grade levels, kindergarten through high school, the skills in the first standards form a nearly continuous sequence. (Please note Appendix, “Science Skills Scope & Sequence.”) It is very important that the Life Science teacher be familiar with the skills in the sequence leading up to standard LS.1 (6.1, 5.1, 4.1).

Standard LS.1

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Expected results are reflected in the organization of the data table, which includes areas to record the number of repeated trials, levels of the independent variable, measured results for the dependent variable, and analysis of the results by calculation of the means.• Systematic investigations require a hypothesis stated in such a way that it identifies the independent variable (parameter that is deliberately changed), the dependent variable (the response that can be measured or observed because of changes in the independent variable), and the relationship between them.• Investigations will use International System of Units (metric units) of measurement.• Mental and physical models can be helpful in explaining events or sequences of events that occur. They can be used as part of scientific explanations to support data or represent phenomena, especially those that are not easily seen directly or must be inferred from data.• Potential sources of error in the experimental design must be identified.• To communicate the plan of an experiment accurately, the independent variable, dependent variable, and constants must be explicitly defined.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• design a data table that includes space to organize all components of an investigation in a meaningful way, including levels of the independent variable, measured responses of the dependent variable, number of trials, and mathematical means.• identify what is deliberately changed in the experiment and what is to be measured as the dependent (responding) variable.• select appropriate tools for collecting qualitative and quantitative data and record measurements (volume, mass, and distance) in metric units..• create physical and mental models as ways to visualize explanations of ideas and phenomena.• evaluate the design of an experiment and the events that occur during an investigation to determine which factors may affect the results of the experiment. This requires students to examine the experimental procedure and decide where or if they have made mistakes.• analyze the variables in an experiment and decide which ones must be held constant (not allowed to change) in order for the investigation to represent a fair test. This requires students to comprehend what “variables” are and to apply that idea in new situations related to the Life Science SOL concepts.

Standard LS.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none"> • To establish that the events of an experiment are the result of manipulating the independent variable, the experiment must be controlled by observing the effects without the application of the independent variable. The results can be compared with this standard or control. Not all experiments have a control. • Multiple trials of an experiment must be conducted to verify the results. • Analysis of observed results of systematic investigations includes construction and interpretation of graphs. Such interpretation can be used to make predictions about the behavior of the dependent variable in other situations and to explore potential sources of error in the experiment. This analysis can be used to support conclusions about the results of the investigation. • Investigations can be classified as <i>observational</i> (descriptive) <i>studies</i> (intended to generate hypotheses), or <i>experimental studies</i> (intended to test hypotheses). • Experimental studies sometimes follow a sequence of steps known as the Scientific Method: stating the problem, forming a hypothesis, testing the hypothesis, recording and analyzing data, stating a conclusion. However, there is no single scientific method. Science requires different abilities and procedures depending on such factors as the field of study and type of investigation. 	<ul style="list-style-type: none"> • determine the specific component of an experiment to be changed as an independent variable and control the experiment by conducting trials for the experiment in which the independent variable is <i>not</i> applied. This requires the student to set up a standard to which the experimental results can be compared. The student must use the results of the controlled trials to determine whether the hypothesized results were indeed due to the independent variable. • construct appropriate graphs, using data sets from experiments. This requires the student to recognize that a line graph is most appropriate for reporting continuous or real-time data. This also requires a student to comprehend that points along the line that are not actual data points can be used to make predictions. Students should be able to interpret and analyze these graphs. • develop conclusions based on a data set and verify whether the data set truly supports the conclusion. This requires students to cite references to the data that specifically support their conclusions. • distinguish between observational and experimental investigations. • identify, describe, and apply the generalized steps of experimental (scientific) methodology.

Standard LS.2

The student will investigate and understand that all living things are composed of cells. Key concepts include

- a) cell structure and organelles (cell membrane, cell wall, cytoplasm, vacuole, mitochondrion, endoplasmic reticulum, nucleus, and chloroplast);
- b) similarities and differences between plant and animal cells;
- c) development of cell theory; and
- d) cell division (mitosis and meiosis).

Understanding the Standard

This standard builds on the general concept in science standard 5.5 that states that living things are made of cells that have different parts. The emphasis here is on the concept that cells are the unit of structure and function of living things and on the concept of subcellular components, or organelles, each with a particular structure and function. The historical contributions of many scientists to the establishment of the cell theory are also important for students to understand. This standard also introduces students to the concept of cell division. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.2

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The cell theory includes the following components: all living things are composed of cells, cells are the smallest unit (structure) of living things that can perform the processes (functions) necessary for life, living cells come only from other living cells.• The development of the cell theory can be attributed to the major discoveries of many notable scientists. The development of the cell theory has been dependent upon improvements in the microscope and microscopic techniques throughout the last four centuries.• Continuing advances in microscopes and instrumentation have increased the understanding of cell organelles and their functions. The structure of a cell organelle reflects the job or function carried out by that organelle. Division of labor within a cell is essential to the overall successful function of the cell.• Many of these organelles can be observed with a compound light microscope.• Similarities and differences in plants and animals are evident at the cellular level. Plant and animal cells contain some of the same organelles and some that differ.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe and sequence the major points in the development of the cell theory.• identify the three components of the cell theory.• distinguish among the following: cell membrane, cytoplasm, nucleus, cell wall, vacuole, mitochondrion, endoplasmic reticulum, and chloroplast.• correlate the structures of cell organelles with their jobs and analyze how organelles perform particular jobs.• compare and contrast examples of plant and animal cells, using the light microscope and images obtained from microscopes.• differentiate between mitosis and meiosis.• design an investigation from a testable question related to animal and plant cells. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. An example of such a question is: “Do onion cells vary in shape or structure depending on where they are found in the plant?”

Standard LS.2 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">Cells go through a life cycle known as the cell cycle. The phases of the cell cycle are interphase, mitosis, and cytokinesis. (Although it is appropriate for students at this level to learn to recognize the stages of the cell cycle, an exploration of the individual stages of meiosis may be reserved for high school Biology.)	<ul style="list-style-type: none">analyze and critique the experimental design of basic investigations related to animal and plant cells. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.

Standard LS.3

The student will investigate and understand that living things show patterns of cellular organization. Key concepts include

- a) cells, tissues, organs, and systems; and
- b) life functions and processes of cells, tissues, organs, and systems (respiration, removal of wastes, growth, reproduction, digestion, and cellular transport).

Understanding the Standard

This standard emphasizes the fact that among living organisms, there is a universality of the functions that maintain life. This standard continues to build upon students' knowledge of these functions and introduces students to the process of cellular transport. With the exception of the structures associated with plant reproduction, which are highlighted in 4.4, this is the students' introduction to the specific structures of plants and animals that enable them to perform life functions. Students are introduced to the concepts of unicellular and multicellular organisms and division of labor. This standard is not intended to require student understanding of the details of human body systems. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.3

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Unicellular organisms are made of only one cell. Multicellular organisms are made of many cells.• Multicellular organisms exhibit a hierarchy of cellular organization. They are complex in that there is a division of labor among the levels of this hierarchy for carrying out necessary life processes.• Cells perform numerous functions and processes, including respiration, waste removal, growth, irritability, and reproduction.• Cells that have the same function group together to form tissues. Tissues that have the same function group together to form organs. Organs with similar functions group to work together in an organ system.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• differentiate between unicellular organisms and multicellular organisms and name common examples of each.• compare and contrast how unicellular and multicellular organisms perform various life functions. This includes the application of knowledge about systems in organisms.• compare and contrast the various basic life functions of an organism, including respiration, waste removal, growth, irritability, and reproduction, and explain the role that each life function serves for an organism.• model how materials move into and out of cells in the processes of osmosis, diffusion, and active transport. This includes creating and interpreting three-dimensional models and/or illustrations demonstrating the processes involved. Students should be able to analyze the components of these models and diagrams and communicate their observations and conclusions.• differentiate among cells, tissue, organs, and organ systems.

Standard LS.3 (continued)

Overview	Essential Knowledge, Skills, and Processes
	<ul style="list-style-type: none">• analyze and critique the experimental design of basic investigations related to understanding cellular organization, with emphasis on observations of cells and tissue. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.

Standard LS.4

The student will investigate and understand that the basic needs of organisms must be met in order to carry out life processes. Key concepts include

- a) plant needs (light, water, gases, nutrients);
- b) animal needs (food, water, gases, shelter, space); and
- c) factors that influence life processes.

Understanding the Standard

The needs of living things are a continuous theme throughout the K-6 standards. This concept is extended here to develop an understanding that when the specific *range* of requirements for these needs are not met, there are consequences in the functioning of an organism. For example, over-watering a plant can be as harmful as under-watering it. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.4

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Plants exhibit needs for light and other energy sources, water, gases, and nutrients. These needs may often be met in a range of conditions. Too much may be as harmful as too little.• Animals exhibit needs for food, water, gases, shelter and space. These needs may often be met in a range of conditions. Too much may be as harmful as too little.• Numerous factors can strongly influence the life processes of organisms.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify the basic needs of all living things.• distinguish between the needs of plants and animals.• explain that there is a specific range or continuum of conditions that will meet the needs of organisms.• explain how organisms obtain the materials that they need.• create plausible hypotheses about the effects that changes in available materials might have on particular life processes in plants and in animals.• design an investigation from a testable question related to animal and plant life needs. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.• analyze and critique the experimental design of basic investigations related to animal and plant needs. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.

Standard LS.5

The student will investigate and understand how organisms can be classified. Key concepts include

- a) the distinguishing characteristics of kingdoms of organisms;
- b) the distinguishing characteristics of major animal and plant phyla; and
- c) the characteristics of the species.

Understanding the Standard

Classifying and grouping is a key inquiry skill, as described in the K–12 “Investigate and Understand” section of the Introduction to the *Science Standards of Learning*. Classifying is an important skill in the K–6 “Scientific Investigation, Reasoning and Logic” strand. The use of a classification key is introduced in 5.1. A key concept of 5.5 is the idea of using characteristics to group organisms into the currently recognized kingdoms.

This standard focuses on students continuing to practice classification skills within a hierarchical biological classification system. This is accomplished by analyzing similarities and differences between the structures and functions of organisms. Students should understand that scientists use classification as a tool to organize information about organisms and to gain information about related organisms. This standard does not require a detailed survey of each kingdom or phylum, but rather a general overview of how organisms are grouped and a focus on a few key groups. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.5

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Information about physical features and activities is arranged in a hierarchy of increasing specificity. The levels in the accepted hierarchy include kingdom, phylum, class, order, family, genus and species.• As living things are constantly being investigated, new attributes are revealed that affect how organisms are placed in a standard classification system.• This system is the basis for scientific nomenclature.• Any grouping of organisms into kingdoms is based on several factors, including the presence or absence of cellular structures such as the nucleus, mitochondria, or a cell wall; whether the organisms exist as single cells or are multi-cellular; and how the organisms get their food. For example, organisms that do not have a nucleus are believed to be fundamentally different from other organisms and may be classified in one or even two different kingdoms. Six different kingdoms of organisms are generally recognized by scientists today.• Some important animal groups (phyla) are the cnidarians, mollusks, annelids, arthropods, echinoderms, and chordates.• Four important plant groups are the mosses, ferns, conifers, and flowering plants.• A group of similar-looking organisms that can interbreed under natural conditions and produce offspring that are capable of reproduction defines a species.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• compare and contrast key features and activities between organisms.• classify organisms based on physical features.• arrange organisms in a hierarchy according to similarities and differences in features.• categorize examples of organisms as representatives of the kingdoms and recognize that the number of kingdoms is subject to change.• recognize scientific names as part of a binomial nomenclature.• recognize examples of major animal phyla.• recognize examples of major plant phyla (divisions).

Standard LS.6

The student will investigate and understand the basic physical and chemical processes of photosynthesis and its importance to plant and animal life. Key concepts include

- a) energy transfer between sunlight and chlorophyll;
- b) transformation of water and carbon dioxide into sugar and oxygen; and
- c) photosynthesis as the foundation of virtually all food webs.

Understanding the Standard

Students learn in 4.4 that photosynthesis is a basic life process of plants requiring chlorophyll and carbon dioxide. This standard pulls these ideas together to demonstrate the complexity and importance of photosynthesis. Energy enters food webs through photosynthesis and is then transferred throughout the food web. It is crucial that students understand the importance of plants (and other photosynthesizing organisms) in this role of providing energy to all other living things. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.6

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none"> • <i>Chlorophyll</i> is a chemical in chloroplasts that can absorb or trap light energy. • <i>Photosynthesis</i> is the necessary life process that transforms light energy into chemical energy. It involves a series of chemical reactions in which the light energy is used to change raw materials (carbon dioxide and water) into products (sugar and oxygen). The energy is stored in the chemical bonds of the glucose (sugar) molecules. • Energy is a basic need of all living things. Photosynthesizing organisms obtain their energy from the sun. Plants and other photosynthesizing organisms are often called producers because of their ability to produce glucose (sugar). • Photosynthesizing organisms are at the base of the energy pyramid. 	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none"> • describe the process of photosynthesis in terms of raw materials and products generated. • identify and describe the organelles involved in the process of photosynthesis. • explain how organisms utilize the energy stored from the products of photosynthesis. • relate the importance of photosynthesis to the role of producers as the foundation of food webs. • design an investigation from a testable question related to photosynthesis. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. • analyze and critique the experimental design of basic investigations related to photosynthesis. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.

Standard LS.7

The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include

- a) the carbon, water, and nitrogen cycles;
- b) interactions resulting in a flow of energy and matter throughout the system;
- c) complex relationships within terrestrial, freshwater, and marine ecosystems; and
- d) energy flow in food webs and energy pyramids.

Understanding the Standard

This standard explores the *application* of the concept of interdependence between organisms and their physical environment. This concept is covered thoroughly in the K–6 standards of the Living Systems strand. The K–6 standards include the concept of interdependence (2.5), relationships in aquatic and terrestrial food chains, trophic levels (3.5 and 6.9), food webs, food pyramids and cycles (6.9), and interactions between the living and nonliving components of an ecosystem (4.5). Terminology used in previous standards includes *producer*, *consumer*, *decomposer* (3.5 and 6.9), *herbivore*, *omnivore*, *carnivore* (3.5), and *niche* (4.5). It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.7

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• In order to understand how an ecosystem functions, one must understand the concept of a system and be able to envision models of systems.• To analyze the interactions resulting in a flow of energy and matter throughout the ecosystem, one must identify the elements of the system and interpret how energy and matter are used by each organism.• Many important elements and compounds cycle through the living and nonliving components of the environment as a chain of events that continuously repeats.• Energy enters an ecosystem through the process of photosynthesis and is passed through the system as one organism eats and is, in turn, eaten. This energy flow can be modeled through relationships expressed in food webs.• Materials are recycled and made available through the action of decomposers.• The amount of energy available to each successive trophic level (producer, first-order consumer, second-order consumer, third-order consumer) decreases. This can be modeled through an energy pyramid, in which the producers provide the broad base that supports the other interactions in the system.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• observe and identify common organisms in ecosystems and collect, record, and chart data concerning the interactions of these organisms (from observations and print and electronic resources).• classify organisms found in local ecosystems as producers or first-, second-, or third-order consumers. Design and construct models of food webs with these organisms.• observe local ecosystems and identify, measure, and classify the living and nonliving components.• differentiate among key processes in the water, carbon, and nitrogen cycles and analyze how organisms, from bacteria and fungi to third-order consumers, function in these cycles.• determine the relationship between a population's position in a food web and its size.• identify examples of interdependence in terrestrial, freshwater, and marine ecosystems.• apply the concepts of food chains, food webs, and energy pyramids to analyze how energy and matter flow through an ecosystem.

Standard LS.7 (continued)

Overview	Essential Knowledge, Skills, and Processes
	<ul style="list-style-type: none">• design an investigation from a testable question related to food webs. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.• analyze and critique the experimental design of basic investigations related to food webs.

Standard LS.8

The student will investigate and understand that interactions exist among members of a population. Key concepts include

- a) competition, cooperation, social hierarchy, territorial imperative; and
- b) influence of behavior on a population.

Understanding the Standard

This standard applies the concept that each organism exists as a member of a population and interacts with other members of that population in a variety of ways. The term *population* is introduced in standard 3.6 (“Living Systems” strand). Individuals of a population demonstrate various behavioral adaptations (competition, cooperation, establishment of a social hierarchy, territorial imperative), which allow the population to survive. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.8

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Individual members of a population interact with each other. These interactions include competing with each other for basic resources, mates, and territory and cooperating with each other to meet basic needs.• The establishment of a social order in a population may insure that labor and resources are adequately shared.• The establishment of a territory ensures that members of a population have adequate habitat to provide for basic resources.• Individual behaviors and group behaviors can influence a population.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• differentiate between the needs of the individual and the needs of a population.• interpret, analyze, and evaluate data from systematic studies and experiments concerning the interactions among members of a population.• determine the relationship between a population's position in a food web and the types of interactions seen among the individuals of the population.• observe and identify populations in ecosystems and collect, record, chart, and interpret data concerning the interactions of these organisms (from observations and print and electronic resources).• analyze and critique the experimental design of basic investigations related to interactions within a population. This analysis and critique should focus on the skills developed in LS.1. Major emphases should include the following: the clarity of predictions and hypotheses, the organization of data tables, the use of metric measures, adequacy of trials and samples, the identification and use of variables, the identification of constants, the use of controls, displays of graphical data, and the support for conclusions.

Standard LS.9

The student will investigate and understand interactions among populations in a biological community. Key concepts include

- a) the relationships among producers, consumers, and decomposers in food webs;
- b) the relationship between predators and prey;
- c) competition and cooperation;
- d) symbiotic relationships; and
- e) niches.

Understanding the Standard

Life Science standard LS.9 applies the concept of interactions between populations of different species. This standard extends the concepts of prior K–6 standards, including those concerning producers, consumers, and decomposers (3.5); predator and prey (3.6); and niches (4.5). This standard introduces the concept of symbiosis and focuses on the symbiotic relationship between parasite and host. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.9

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• In a community, populations interact with other populations by exhibiting a variety of behaviors that aid in the survival of the population.• Organisms or populations that rely on each other for basic needs form interdependent communities.• Energy resources of a community are shared through the interactions of producers, consumers, and decomposers.• The interaction between a consumer that hunts for another consumer for food is the predator-prey relationship.• Populations of one species may compete with populations of other species for resources. Populations of one species may also cooperate with populations of other species for resources.• A symbiotic relationship may exist between two or more organisms of different species when they live and work together.• Symbiotic relationships include mutualism (in which both organisms benefit), commensalism (in which one organism benefits and the other is unaffected), and parasitism (in which one organism benefits and the other is harmed).• Each organism fills a specific role or niche in its community.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify the populations of producers, consumers, and decomposers and describe the roles they play in their communities.• interpret, analyze, and evaluate data from systematic studies and experiments concerning the interactions of populations in an ecosystem.• predict the effect of population changes on the food web of a community.• generate predictions based on graphically represented data of predator-prey populations.• generate predictions based on graphically represented data of competition and cooperation between populations.• differentiate between the types of symbiosis and explain examples of each.• infer the niche of organisms from their physical characteristics.• design an investigation from a testable question related to interactions among populations. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.

Standard LS.10

The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include

- a) differences between ecosystems and biomes;
- b) characteristics of land, marine, and freshwater ecosystems; and
- c) adaptations that enable organisms to survive within a specific ecosystem.

Understanding the Standard

In standard LS.10, students explore the scheme of the Earth as a group of living systems. Students are asked to distinguish between ecosystems and biomes. The teacher should be aware that in previous standards, students have explored environments as discrete units or have examined individual components. In standard 3.6 students are introduced to the concept of water environments (pond, marshland, swamp, stream, river, and ocean) and land environments (desert, grassland, rainforest, and forest). It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.10

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The living organisms within a specific area and their physical environment define an ecosystem.• The major terrestrial ecosystems are classified into units called biomes — large regions characterized by certain conditions, including a range of climate and ecological communities adapted to those conditions.• Organisms have specific structures, functions, and behaviors that enable them to survive the conditions of the particular ecosystem in which they live.• Organisms adapt to both biotic and abiotic factors in their ecosystem.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• differentiate between ecosystems and biomes.• recognize and give examples of major biomes: desert, forest, grassland, and tundra.• compare and contrast the biotic and abiotic characteristics of land, marine, and freshwater ecosystems.• observe and describe examples of specific adaptations that organisms have which enable them to survive in a particular ecosystem.• analyze specific adaptations of organisms to determine how they help the species survive in its ecosystem.• design an investigation from a testable question related to how organisms adapt to biotic and abiotic factors in a ecosystems. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.• analyze and critique the experimental design of basic investigations related to how organisms adapt to biotic and abiotic factors in ecosystems.

Standard LS.11

The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time (daily, seasonal, and long term). Key concepts include

- a) phototropism, hibernation, and dormancy;
- b) factors that increase or decrease population size; and
- c) eutrophication, climate changes, and catastrophic disturbances.

Understanding the Standard

In standard LS.11, students apply the concept of change over time to several specific situations. As conditions change, organisms, populations, communities, and ecosystems respond to those changes in order to survive. The key concepts are given in a sequence from responses of individual organisms (phototropism, hibernation, and dormancy) to responses of populations (factors that increase or decrease population size) to responses of communities or ecosystems (eutrophication, climate change, and catastrophic disturbances).

The concepts of standard LS.11 focus on the theme of change. Living units respond in various ways to change. A key concept is the understanding of the dynamic nature of living systems as they constantly respond to change. Change is referenced several times in the K–6 standards. In the “Earth Patterns, Cycles, and Change” strand, the following concepts are introduced: natural and human-made things may change over time (K.9); temperature, light, and precipitation bring about changes (1.7); and weather and seasonal changes affect plants, animals, and their surroundings (2.7). In the “Life Processes” strand, the following concepts are introduced: animals respond to life needs through hibernation, migration, camouflage, etc. (3.4); and basic plant processes include the responses of reproduction, photosynthesis, dormancy (4.4). It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.11

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Organisms may exist as members of a population; populations interact with other populations in a community; and communities together with the physical environment form ecosystems.• Changes that affect organisms over time may be daily, seasonal, or long-term.• Plants may respond to light by growing toward it or away from it, a behavior known as <i>phototropism</i>.• Animals may respond to cold conditions with a period of lowered metabolism, a behavior known as <i>hibernation</i>.• Organisms may respond to adverse conditions with a period of lowered or suspended metabolism, a behavior known as <i>dormancy</i>.• A variety of environmental factors may cause the size of a population to increase or decrease. (This requires students to brainstorm examples of factors and predict the possible effects.)• Large-scale changes may affect entire communities and ecosystems. Such large-scale changes include the addition of excess nutrients to the system (eutrophication), which alters environmental balance; dramatic changes in climate; and catastrophic events, such as fire, drought, flood, and earthquakes.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• relate the responses of organisms to daily, seasonal, or long-term events.• differentiate between ecosystems, communities, populations, and organisms.• predict the effect of climate change on ecosystems, communities, populations, and organisms.• compare and contrast the factors that increase or decrease population size.• predict the effect of large scale changes on ecosystems, communities, populations, and organisms.• classify the various types of changes that occur over time in ecosystems, communities, populations, and organisms.• design an investigation from a testable question related to change over time in ecosystems, communities, populations, or organisms. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.• analyze and critique the experimental design of basic investigations related to change over time in ecosystems, communities, populations, and organisms.

Standard LS.12

The student will investigate and understand the relationships between ecosystem dynamics and human activity. Key concepts include

- a) food production and harvest;
- b) change in habitat size, quality, or structure;
- c) change in species competition;
- d) population disturbances and factors that threaten or enhance species survival; and
- e) environmental issues (water supply, air quality, energy production, and waste management).

Understanding the Standard

In this standard, students are called upon to apply their knowledge of human interactions to interpret how these interactions affect ecosystem dynamics. In prior standards in the “Resources” strand of the K–6 standards, students explore a variety of ways in which humans interact with the environment. These include the concepts of waste management (K.10, 1.8), limitations of natural resources and factors that affect environmental quality (1.8, 3.10), Virginia’s natural resources (4.8), and public policy decisions relating to the environment (6.9). In this Life Science standard, the student must interpret how human populations can change the balance of nature in ecosystems. They must use their prior knowledge of resources as well as the concepts and skills learned in Life Science standards LS.7 – LS.11. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.12

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Ecosystems are dynamic systems.• Humans are a natural part of the ecosystem. Humans use the ecosystem to meet their basic needs, such as to obtain food.• Human interaction can directly alter habitat size, the quality of available resources in a habitat, and the structure of habitat components. Such interactions can be positive and/or negative.• Human input can disturb the balance of populations that occur in a stable ecosystem. These disturbances may lead to a decrease or increase in a population. Since populations in an ecosystem are interdependent, these disturbances have a ripple effect throughout the ecosystem.• The interaction of humans with the dynamic ecosystem may lead to issues of concern for continued ecosystem health in areas such as water supply, air quality, energy production, and waste management.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• identify examples of ecosystem dynamics.• describe the relationship between human food harvest and the ecosystem.• describe ways that human interaction has altered habitats positively and negatively.• debate the pros and cons of human land use versus ecosystem stability.• compare and contrast population disturbances that threaten and those that enhance species survival.• observe the effect of human interaction in local ecosystems and collect, record, chart, and interpret data concerning the effect of interaction (from observations and print and electronic resources).• design an investigation from a testable question related to the relationships between ecosystem dynamics and human activity. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.• analyze and critique the experimental design of basic investigations related to the relationships between ecosystem dynamics and human activity.

Standard LS.13

The student will investigate and understand that organisms reproduce and transmit genetic information to new generations. Key concepts include

- a) the role of DNA;
- b) the function of genes and chromosomes;
- c) genotypes and phenotypes;
- d) factors affecting the expression of traits;
- e) characteristics that can and cannot be inherited;
- f) genetic engineering and its applications; and
- g) historical contributions and significance of discoveries related to genetics.

Understanding the Standard

In science standard 2.7, students are introduced to the general notion that plants and animals resemble their parents. This Life Science standard is the students' introduction to genetics. It is important for the teacher to understand that the intent of this standard is to provide students with a general overview of the nature of DNA, genes, and chromosomes and the important role they play in the transmission of traits from one generation to another. Students are not expected to understand the specific chemical composition of DNA or the mechanics of transcription and translation. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.13

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• DNA is a double helix molecule.• DNA is a molecule that includes different components — sugars, nitrogenous bases, and phosphates. The arrangement of the nitrogenous bases within the double helix forms a chemical code.• Chromosomes are strands of tightly wound DNA. Genes are sections of a chromosome that carry the code for a particular trait.• The basic laws of Mendelian genetics explain the transmission of most traits that can be inherited from generation to generation.• Traits that are expressed through genes can be inherited. Characteristics that are acquired through environmental influences, such as injuries or practiced skills, cannot be inherited.• In genetic engineering, the genetic code is manipulated to obtain a desired product.• Genetic engineering has numerous practical applications in medicine, agriculture, and biology.• A series of contributions and discoveries led to the current level of genetic science.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• recognize the appearance of DNA as double helix in shape.• explain that DNA contains coded instructions that store and pass on genetic information from one generation to the next.• demonstrate variation within a single genetic trait.• explain the necessity of DNA replication for the continuity of life.• differentiate between characteristics that can be inherited and those that cannot be inherited.• distinguish between dominant and recessive traits.• distinguish between genotype and phenotype.• use Punnett squares to predict the possible combinations of inherited factors resulting from single trait crosses.• identify aspects of genetic engineering and supply examples of applications. Evaluate the examples for possible controversial aspects.• describe the contributions of Mendel, Franklin, and Watson and Crick to our basic understanding of genetics.

Standard LS.14

The student will investigate and understand that organisms change over time. Key concepts include

- a) the relationships of mutation, adaptation, natural selection, and extinction;
- b) evidence of evolution of different species in the fossil record; and
- c) how environmental influences, as well as genetic variation, can lead to diversity of organisms.

Understanding the Standard

Standard LS.14 explores the concept of evolution. Species respond to changes in their environments through adaptations. This is a gradual process that occurs over long periods of time. The progression of these long-term changes is well documented in the fossil record. Evolution, as a big organizing principle of the life sciences, establishes order among the great variety of living things.

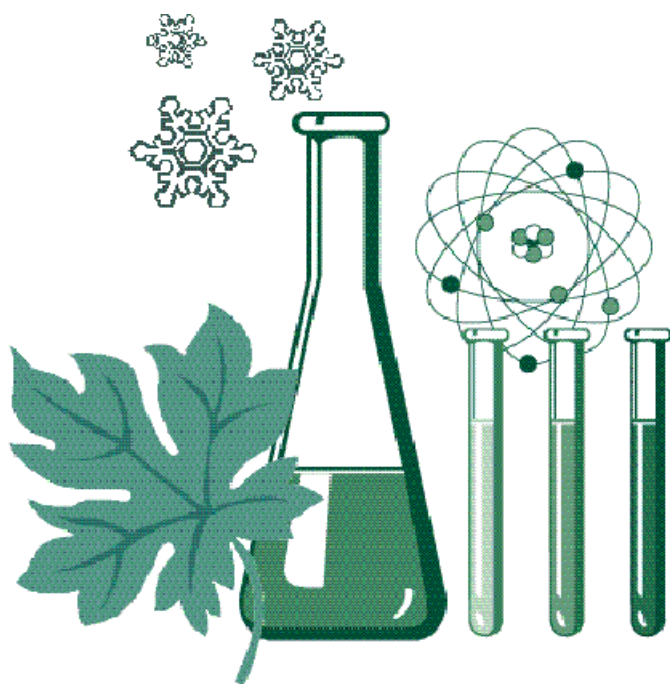
There are many misconceptions about evolution; therefore teachers must be careful to be accurate in their presentation of this scientific theory. One common misconception among students is that they believe that environmental influences on an organism produce changes in that organism that can be passed on to offspring. However, selection can only work through the genetic variation that is already present in the population. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (LS.1) in the context of the key concepts presented in this standard.

Standard LS.14

Overview	Essential Knowledge, Skills, and Processes
<p>The concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The mechanisms through which evolution takes place are a related set of processes that include mutation, adaptation, natural selection, and extinction.• Mutations are inheritable changes because a mutation is a change in the DNA code.• Adaptations are structures, functions, or behaviors that enable a species to survive.• A mutation may result in a favorable change or adaptation in genetic information that improves a species' ability to exist in its environment, or a mutation may result in an unfavorable change that does not improve or impedes a species' ability to exist in its environment.• Individuals of a population exhibit a range of variations in a trait as a result of the variations in their genetic codes.• The evidence for evolution is drawn from a variety of sources of data, including the fossil record, radiometric dating, genetic information, the distribution of organisms, and anatomical and developmental similarities across species.• Natural selection is the survival and reproduction of the individuals in a population that exhibit the traits that best enable them to survive in their environment.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain how genetic variations in offspring, which lead to variations in successive generations, can result from the same two parents..• describe how changes in the environment can bring about changes in species through natural selection, adaptation, and extinction.• describe and explain how fossils are records of organisms and events in the Earth's history.• explain the evidence for evolution from a variety of sources of scientific data.• analyze and evaluate data from investigations on variations within a local population.• interpret data from simulations that demonstrate selection for a trait belonging to species in various environments.

Standard LS.14 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• If a species does not include traits that enable it to survive in its environment or to survive changes in the environment, then the species may become extinct.	



Science Standards of Learning Curriculum Framework

Physical Science

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Standard PS.1

The student will plan and conduct investigations in which

- a) chemicals and equipment are used safely;
- b) length, mass, volume, density, temperature, weight, and force are accurately measured and reported using metric units (SI — International System of Units);
- c) conversions are made among metric units, applying appropriate prefixes;
- d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and spring scales are used to gather data;
- e) numbers are expressed in scientific notation where appropriate;
- f) research skills are utilized using a variety of resources;
- g) independent and dependent variables, constants, controls, and repeated trials are identified;
- h) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted;
- i) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted;
- j) frequency distributions, scattergrams, line plots, and histograms are constructed and interpreted;
- k) valid conclusions are made after analyzing data;
- l) research methods are used to investigate practical problems and questions;
- m) experimental results are presented in appropriate written form; and
- n) an understanding of the nature of science is developed and reinforced.

Understanding the Standard

The skills described in standard PS.1 are intended to define the “investigate” component of all of the other Physical Science standards (PS.2 – PS.11). The intent of standard PS.1 is that students will continue to develop a range of inquiry skills and achieve proficiency with those skills in the context of the concepts developed in the Physical Science curriculum. Standard PS.1 does not require a discrete unit on scientific investigation because the inquiry skills that make up the standard should be incorporated in all the other Physical Science standards. It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science, as well as more fully grasp the content-related SOL concepts.

Across the grade levels, kindergarten through high school, the skills in the first standards form a nearly continuous sequence. (Please note Appendix, “Science Skills Scope & Sequence.”) It is very important that the Physical Science teacher be familiar with the skills in the sequence leading up to standard PS.1 (LS.1, 6.1, 5.1, 4.1).

Standard PS.1

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Systematic investigations require standard measures and consistent and reliable tools. SI (metric) measures, recognized around the world, are a standard way to make measurements.• Systematic investigations require organized reporting of data. The way the data are displayed can make it easier to see important patterns, trends, and relationships. Frequency distributions, scattergrams, line plots, and histograms are powerful tools for displaying and interpreting data.• Investigation not only involves the careful application of systematic (scientific) methodology, but also includes the review and analysis of prior research related to the topic. Numerous sources of information are available from print and electronic sources, and the researcher needs to judge the authority and credibility of the sources.• To communicate the plan of an experiment accurately, the independent variable, dependent variable, and constants must be explicitly defined.• The number of repeated trials needs to be considered in the context of the investigation. Often “controls” are used to establish a standard for comparing the results of manipulating the independent variable. Controls receive no experimental treatment. Not all experiments have a control, however.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• select appropriate equipment (triple beam balances, thermometers, metric rulers, graduated cylinders, electronic balances, or spring scales) and utilize correct techniques to measure length, mass, density, weight, volume, temperature, and force.• design a data table that includes space to organize all components of an investigation in a meaningful way, including levels of the independent variable, measured responses of the dependent variable, number of trials, and mathematical means.• record measurements, using the following metric (SI) units: liter, milliliter (cubic centimeters), meter, centimeter, millimeter, grams, degrees Celsius, and newtons.• recognize metric prefix units and make common metric conversions between the same base metric unit (for example, milligram to gram or kilometer to meter).

Standard PS.1 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none"> • The analysis of data from a systematic investigation may provide the researcher with a basis to reach a reasonable conclusion. Conclusions should not go beyond the evidence that supports them. Additional scientific research may yield new information that affects previous conclusions. • Different kinds of problems and questions require differing approaches and research. Scientific methodology almost always begins with a question, is based on observation and evidence, and requires logic and reasoning. Not all systematic investigations are experimental. • It is important to communicate systematically the design and results of an investigation so that questions, procedures, tools, results, and conclusions can be understood and replicated. • Scientists rely on creativity and imagination during all stages of their investigations. 	<ul style="list-style-type: none"> • use a variety of graphical methods to display data; create an appropriate graph for a given set of data; and select the proper type of graph for a given set of data, identify and label the axes, and plot the data points. (<i>Note: Frequency distributions, scattergrams, line plots, and histograms are described in the Mathematics Curriculum Framework, standard 7.17, pp. 27–29.</i>) • gather, evaluate, and summarize information, using multiple and variable resources, and detect bias from a given source. • identify the key components of controlled experiments: hypotheses, independent and dependent variables, constants, controls, and repeated trials. • formulate conclusions that are supported by the gathered data. • apply the methodology of scientific inquiry: begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. • communicate in written form the following information about investigations: the purpose/problem of the investigation, procedures, materials, data and/or observations, graphs, and an interpretation of the results. • describe how creativity comes into play during various stages of scientific investigations.

Standard PS.2

The student will investigate and understand the basic nature of matter. Key concepts include

- a) the particle theory of matter;
- b) elements, compounds, mixtures, acids, bases, and salts;
- c) solids, liquids, and gases;
- d) characteristics of types of matter based on physical and chemical properties;
- e) physical properties (shape, density, solubility, odor, melting point, boiling point, color); and
- f) chemical properties (acidity, basicity, combustibility, reactivity).

Understanding the Standard

The concepts in PS.2 build upon several science standards from previous grades, including K.4, 1.3, 2.3, 3.3, 5.4, and 6.4. These standards introduce and develop basic ideas about the characteristics and structure of matter. In PS.2, the ideas and terminology continue to be expanded and treated in greater depth, including more mathematical application. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.2

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• <i>Matter</i> is anything that has mass and occupies space. All matter is made up of small particles called atoms. Matter can exist as a solid, a liquid, or a gas.• Matter can be classified as elements, compounds, and mixtures. The atoms of any element are alike but are different from atoms of other elements. Compounds consist of two or more elements that are chemically combined in a fixed ratio. Mixtures also consist of two or more substances, but the substances are not chemically combined.• Compounds can be classified in several ways, including:<ul style="list-style-type: none">- acids, bases, salts- inorganic and organic compounds.• Acids make up an important group of compounds that contain hydrogen ions. When acids dissolve in water, hydrogen ions (H^+) are released into the resulting solution. A base is a substance that releases hydroxide ions (OH^-) into solution. pH is a measure of the hydrogen ion concentration in a solution. The pH scale ranges from 0–14. Solutions with a pH lower than 7 are acidic; solutions with a pH greater than 7 are basic. A pH of 7 is neutral. When an acid reacts with a base, a salt is formed, along with water.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe the particle theory of matter.• describe the properties of the states of matter (solid, liquid, and gas).• describe how to determine whether a substance is an element, compound, or mixture.• define compounds as inorganic or organic. (All organic compounds contain carbon.)• distinguish between physical properties (i.e., shape, density, solubility, odor, melting point, boiling point, and color) and chemical properties (i.e., acidity, basicity, combustibility, and reactivity).• find the mass and volume of substances and calculate and compare their densities.• analyze the pH of a solution and classify it as acidic, basic, or neutral.• describe what a salt is and explain how salts form.• determine the identity of an unknown substance by comparing its properties to those of known substances.

Standard PS.2 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Matter can be described by its physical properties, which include shape, density, solubility, odor, melting point, boiling point, and color. Some physical properties, such as density, boiling point, and solubility, are characteristic of a specific substance and do not depend on the size of the sample. Characteristic properties can be used to identify unknown substances.• Equal volumes of different substances usually have different masses.• Matter can also be described by its chemical properties, which include acidity, basicity, combustibility, and reactivity. A chemical property indicates whether a substance can undergo a chemical change.	<ul style="list-style-type: none">• design an investigation from a testable question related to physical and chemical properties of matter. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. (Students should be able to use the inquiry skills represented in PS.1 and LS.1 to compose a clear hypothesis, create an organized data table, identify variables and constants, record data correctly, construct appropriate graphs, analyze data, and draw reasonable conclusions.)

Standard PS.3

The student will investigate and understand the modern and historical models of atomic structure. Key concepts include

- a) the contributions of Dalton, Thomson, Rutherford, and Bohr in understanding the atom; and
- b) the modern model of atomic structure.

Understanding the Standard

PS.3 builds upon science standards 3.3, 5.4, and 6.4, which introduce basic concepts and terminology related to the atom. PS.3 focuses more specifically on the basic structure of the atom and how models have been and are used to explain atomic structure. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.3

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• The atom is the basic building block of matter and consists of subatomic particles (proton, neutron, and electron) that differ in their location, charge, and relative mass.• Scientists use models to help explain the structure of the atom. Their understanding of the structure of the atom continues to evolve. Two models commonly used are the Bohr and the “electron cloud” (Quantum Mechanics) models. The Bohr model does not depict the three-dimensional aspect of an atom, and it implies that electrons are in static orbits. The “electron cloud” model better represents our current understanding of the structure of the atom.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• describe the historical development of the concept of the atom and the contributions of Dalton, Thomson, Rutherford, and Bohr.• use the Bohr model to differentiate among the three basic particles in the atom (proton, neutron, and electron) and their charges, relative masses, and locations.• compare the Bohr atomic model to the electron cloud model with respect to their ability to represent accurately the three-dimensional structure of the atom.

Standard PS.4

The student will investigate and understand the organization and use of the periodic table of elements to obtain information. Key concepts include

- a) symbols, atomic number, atomic mass, chemical families (groups), and periods;
- b) classification of elements as metals, metalloids, and nonmetals; and
- c) simple compounds (formulas and the nature of bonding).

Understanding the Standard

PS.4 formally introduces the periodic table of elements. This standard builds upon concepts of the atom presented in science standard 6.4. Standard PS.4 focuses on a student's ability to look at the organization of the periodic table and learn what information can be obtained from it. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.4

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• There are more than 110 known elements. No element with an atomic number greater than 92 is found naturally in measurable quantities on Earth. The remaining elements are artificially produced in a laboratory setting. Elements combine in many ways to produce compounds that make up all other substances on Earth.• The periodic table of elements is a tool used to organize information about the elements. Each box in the periodic table contains information about the structure of an element.• An atom's identity is directly related to the number of protons in its nucleus. This is the basis for the arrangement of atoms on the periodic table of elements.• The periodic table of elements is an arrangement of elements according to atomic number and properties. The information can be used to predict chemical reactivity. The boxes for all of the elements are arranged in increasing order of atomic number. The elements have an increasing nonmetallic character as one reads from left to right across the table. Along the stair-step line are the metalloids, which have properties of both metals and nonmetals.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• use the periodic table to obtain the following information about the atom of an element:<ul style="list-style-type: none">- symbol- atomic number- atomic mass- state of matter at room temperature- number of outer energy level (valence) electrons.• describe the organization of the periodic table in terms of<ul style="list-style-type: none">- atomic number- metals, metalloids, and nonmetals- groups/families vs. periods.• categorize a given element as metal, non-metal, or metalloid.• given a chemical formula of a compound, identify the elements and the number of atoms of each that comprise the compound.• recognize that the number of electrons in the outermost energy level determines an element's chemical properties or chemical reactivity.• predict what kind of bond (ionic or covalent) will likely form when metals and nonmetals combined chemically.

Standard PS.4 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• The nonmetals are located to the right of the stair-step line on the periodic table.• Metals tend to lose electrons in chemical reactions, forming positive ions. Nonmetals tend to gain electrons in chemical reactions, forming negative ions.• Gaining or losing electrons makes an atom an ion. Gaining or losing neutrons makes an atom an isotope. However, gaining or losing a proton makes an atom into a completely different element.• The vertical columns in the table are called groups or families. Elements in each group have similar properties because they have the same number of electrons in the outermost energy level. The horizontal rows are called periods.• Elements in the same column (family) of the periodic table contain the same number of electrons in their outer energy levels. This gives rise to their similar properties and is the basis of periodicity — the repetitive pattern of properties such as boiling point across periods on the table.	<ul style="list-style-type: none">• describe the difference between ionic and covalent bonding.• recognize that an atom's identity is related to the number of protons in its nucleus.

Standard PS.4 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Atoms react to form chemically stable substances that are held together by chemical bonds and are represented by chemical formulas. To become chemically stable, atoms gain, lose, or share electrons.• Compounds are formed when elements react chemically. When a metallic element reacts with a nonmetallic element, their atoms gain and lose electrons respectively, forming ionic bonds. Generally, when two nonmetals react, atoms share electrons, forming covalent (molecular) bonds.	

Standard PS.5

The student will investigate and understand changes in matter and the relationship of these changes to the Law of Conservation of Matter and Energy. Key concepts include

- a) physical changes;
- b) nuclear reactions (products of fusion and fission and the effect of these products on human beings and the environment); and
- c) chemical changes (types of reactions, reactants, and products; and balanced equations).

Understanding the Standard

This standard focuses on the concept that matter and energy can be changed in different ways, but the total amount of mass and energy is conserved. Students have previously investigated physical and chemical changes. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.5

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Matter can undergo physical and chemical changes. In physical changes, the chemical composition of the substances does not change. In chemical changes, different substances are formed.• The Law of Conservation of Matter (Mass) states that regardless of how substances within a closed system are changed, the total mass remains the same. The Law of Conservation of Energy states that energy cannot be created or destroyed but only changed from one form to another.• A chemical equation represents the changes that take place in a chemical reaction. The chemical formulas of the reactants are written on the left, an arrow indicates a change to new substances, and the chemical formulas of the products are written on the right. Chemical reactions are classified into two broad types: ones in which energy is released (exothermic) and ones in which energy is absorbed (endothermic). (The study of synthesis, decomposition, and replacement reactions can be reserved for high school Chemistry.)	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• compare and contrast physical, chemical, and nuclear changes.• design an investigation that illustrates physical and chemical changes.• given chemical formulas, write and balance simple chemical equations.• analyze experimental data to determine whether it supports the Law of Conservation of Mass.• recognize that some types of chemical reactions require continuous input of energy (endothermic) and others release energy (exothermic).• describe, in simple terms, the processes that release nuclear energy (i.e., nuclear fission and nuclear fusion). Create a simple diagram to summarize and compare and contrast these two types of nuclear energy.• evaluate the positive and negative effects of using nuclear energy.

Standard PS.5 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• Another type of change occurs in nuclear reactions. Nuclear energy is the energy stored in the nucleus of an atom. This energy can be released by joining nuclei together (fusion) or by splitting nuclei (fission), resulting in the conversion of minute amounts of matter into energy. In nuclear reactions, a small amount of matter produces a large amount of energy. However, there are potential negative effects of using nuclear energy, including radioactive nuclear waste storage and disposal.	

Standard PS.6

The student will investigate and understand states and forms of energy and how energy is transferred and transformed.

Key concepts include

- a) potential and kinetic energy;
- b) mechanical, chemical, and electrical energy; and
- c) heat, light, and sound.

Understanding the Standard

The concepts in PS.6 build upon several science standards from previous grades, including 4.2, 4.3, 5.3, 6.3, and 6.4. These standards introduce and develop basic ideas about states and forms of energy. At the sixth grade level, this sequence culminates with the idea about energy transformations. In PS.6, concepts about energy forms, energy transformations, and potential and kinetic energy continue to be expanded and treated in greater depth, including more mathematical application. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.6

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• <i>Energy</i> is the ability to do work.• Energy exists in two states. <i>Potential energy</i> is stored energy based on position or chemical composition. <i>Kinetic energy</i> is energy of motion. Students should know that the amount of potential energy associated with an object depends on its position. The amount of kinetic energy depends on the mass and velocity of the moving object.• Important forms of energy include light, heat, chemical, electrical, mechanical, and nuclear energy. Sound is a form of mechanical energy.• Energy can be transformed from one type to another. In any energy conversion, some of the energy is lost to the environment as heat.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• differentiate between potential and kinetic energy.• use diagrams or concrete examples to compare relative amounts of potential and kinetic energy.• identify and give examples of common forms of energy.• design an investigation or create a diagram to illustrate energy transformations.

Standard PS.7

The student will investigate and understand temperature scales, heat, and heat transfer. Key concepts include

- a) Celsius and Kelvin temperature scales and absolute zero;
- b) phase change, freezing point, melting point, boiling point, vaporization, and condensation;
- c) conduction, convection, and radiation, and
- d) applications of heat transfer (heat engines, thermostats, refrigeration, and heat pumps).

Understanding the Standard

This standard focuses on how heat affects matter and how heat is transferred. Concepts introduced in previous grades and related to the states of matter are presented in standards 2.3 and 5.4. More complex concepts and terminology related to phase changes are introduced in PS.7, including the distinction between heat and temperature. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.7

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Atoms and molecules are perpetually in motion.• Increased temperature means greater average kinetic energy of the substance being measured, and most substances expand when heated. The temperature of absolute zero ($-273^{\circ}\text{C}/0^{\circ}\text{K}$) is the theoretical point at which molecular motion stops.• The transfer of heat occurs in three ways: by conduction, by convection, and by radiation.• Heat and temperature are not the same thing. As heat energy is added to or taken away from a system, the temperature does not always change. There is no change in temperature during a phase change (freezing, melting, condensing, boiling, and vaporizing) as this energy is being used to make or break bonds between molecules.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• illustrate and explain the effect of the addition or subtraction of heat energy on the motion of molecules.• distinguish between heat and temperature.• compare and contrast Celsius and Kelvin temperature scales and describe absolute zero.• analyze a time/temperature graph of a phase change experiment to determine the temperature at which the phase change occurs (freezing point, melting point, or boiling point).• compare and contrast conduction, convection, and radiation and provide and explain common examples.• explain, in simple terms, how the principle of heat transfer applies to heat engines, thermostats, and refrigerators and heat pumps.• design an investigation from a testable question related to heat transfer. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis.

Standard PS.8

The student will investigate and understand characteristics of sound and technological applications of sound waves. Key concepts include

- a) wavelength, frequency, speed, and amplitude;
- b) resonance;
- c) the nature of mechanical waves; and
- d) technological applications of sound.

Understanding the Standard

The focus of this standard is the mechanical wave-like nature of sound and some examples of its application. Sound is introduced in science standard 5.2, and it is expected that standard PS.8 will build upon and expand the concepts of the earlier standard. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.8

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Sound is produced by vibrations and is a type of mechanical energy. Sound travels in compression waves and at a speed much slower than light. It needs a medium (solid, liquid, or gas) in which to travel. In a compression wave, matter vibrates in the same direction in which the wave travels.• All waves exhibit certain characteristics: wavelength, frequency, and amplitude. As wavelength increases, frequency decreases.• A longitudinal wave consists of a repeating pattern of compressions and rarefactions. Wavelength is measured as the distance from one compression to the next compression or the distance from one rarefaction to the next rarefaction.• The speed of sound depends on two things: the medium through which the waves travel and the temperature of the medium.• Reflection and interference patterns are used in ultrasonic technology, including sonar and medical diagnosis.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• model a compression (longitudinal) wave and diagram, label, and describe the basic components: wavelength, compression, rarefaction, and frequency.• determine the relationship between frequency and wavelength.• analyze factors that determine the speed of sound through various materials and interpret graphs and charts that display this information.• describe technological applications of sound waves and generally how each application functions.• design an investigation from a testable question related to sound. The investigation may be a complete experimental design or may focus on systematic observation, description, measurement, and/or data collection and analysis. (Students should be able to use the inquiry skills represented in PS.1 and LS.1 to compose a clear hypothesis, create an organized data table, identify variables and constants, record data correctly, construct appropriate graphs, analyze data, and draw reasonable conclusions.)

Standard PS.9

The student will investigate and understand the nature and technological applications of light. Key concepts include

- a) the wave behavior of light (reflection, refraction, diffraction, and interference);
- b) images formed by lenses and mirrors; and
- c) the electromagnetic spectrum.

Understanding the Standard

This standard focuses on the nature of light and its applications. It builds upon standard 5.3, in which students investigate the characteristics of visible light. Standard PS.9 introduces students to the wave behavior of light. The speed of light in a vacuum is a constant. Light can change speed and direction as a result of moving from one medium to another. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.9

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Light travels in straight lines until it strikes an object where it can be reflected, absorbed, or transmitted. As light waves travel through different media, they undergo a change in speed that may result in refraction.• Light is a form of radiant energy that moves in transverse waves.• There is an inverse relationship between frequency and wavelength.• Electromagnetic waves are arranged on the electromagnetic spectrum by wavelength. All types of electromagnetic radiation travel at the speed of light, but differ in wavelength. The electromagnetic spectrum includes gamma rays, X-rays, ultraviolet, visible light, infrared, and radio and microwaves.• Radio waves are the lowest energy waves and have the longest wavelength and the lowest frequency. Gamma rays are the highest energy waves and have the shortest wavelength and the highest frequency. Visible light lies in between and makes up only a small portion of the electromagnetic spectrum.	<p>In order to meet this standard, it is expected that students should be able</p> <ul style="list-style-type: none">• design an investigation to illustrate the behavior of visible light – reflection and refraction. Describe how reflection and refraction occur.• describe the wave theories of light.• model a transverse wave and draw and label the basic components. Explain wavelength, amplitude, and frequency.• compare the various types of electromagnetic waves in terms of wavelength, frequency, and energy.• describe an everyday application of each of the major forms of electromagnetic energy.

Standard PS.10

The student will investigate and understand scientific principles and technological applications of work, force, and motion. Key concepts include

- a) speed, velocity, and acceleration;
- b) Newton's laws of motion;
- c) work, force, mechanical advantage, efficiency, and power; and
- d) applications (simple machines, compound machines, powered vehicles, rockets, and restraining devices).

Understanding the Standard

PS.10 builds upon the concepts of simple machines, force, and work introduced in science standards 3.2 and 4.2. Standard PS.10 reviews and expands these basic ideas and introduces students to more mathematical concepts of motion. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.10

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• A force is a push or pull. Force is measured in newtons. Force can cause objects to move, stop moving, change speed, or change direction. <i>Speed</i> is the change in position of an object per unit of time. Velocity may have a positive or a negative value depending on the direction of the change in position, whereas speed always has a positive value and is nondirectional.• Newton's three laws of motion describe the motion of all common objects.• <i>Acceleration</i> is the change in velocity per unit of time. An object moving with constant velocity has no acceleration. A decrease in velocity is negative acceleration or <i>deceleration</i>. A distance-time graph for acceleration is always a curve. Objects moving with circular motion are constantly accelerating because direction (and hence velocity) is constantly changing.• Mass and weight are not equivalent. <i>Mass</i> is the amount of matter in a given substance. <i>Weight</i> is a measure of the force due to gravity acting on a mass. Weight is measured in newtons.• Work is done when an object is moved through a distance in the direction of the applied force.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• make measurements to calculate the speed of a moving object.• apply the concepts of speed, velocity, and acceleration when describing motion.• explain how force, mass, and acceleration are related.• differentiate between mass and weight.• identify situations that illustrate each Law of Motion.• apply the concept of mechanical advantage to test and explain how a machine makes work easier.• make measurements to calculate the work done on an object.• make measurements to calculate the power of an object.• explain how the concepts of work, force, and motion apply to car safety technology, machines, and rockets.• solve basic problems given the following formulas: Speed = distance/time ($s = d/t$) Force = mass \times acceleration ($F = ma$) Work = force \times distance ($W = Fd$) Power = work/time ($P = W/t$).

Standard PS.10 (continued)

Overview	Essential Knowledge, Skills, and Processes
<ul style="list-style-type: none">• A simple machine is a device that makes work easier. Simple machines have different purposes: to change the effort needed (mechanical advantage), to change the direction or distance through which the force is applied, to change the speed at which the resistance moves, or a combination of these. Due to friction, the work put into a machine is always greater than the work output. The ratio of work output to work input is called <i>efficiency</i>.• Mathematical formulas are used to calculate speed, force, work, and power.	

Standard PS.11

The student will investigate and understand basic principles of electricity and magnetism. Key concepts include

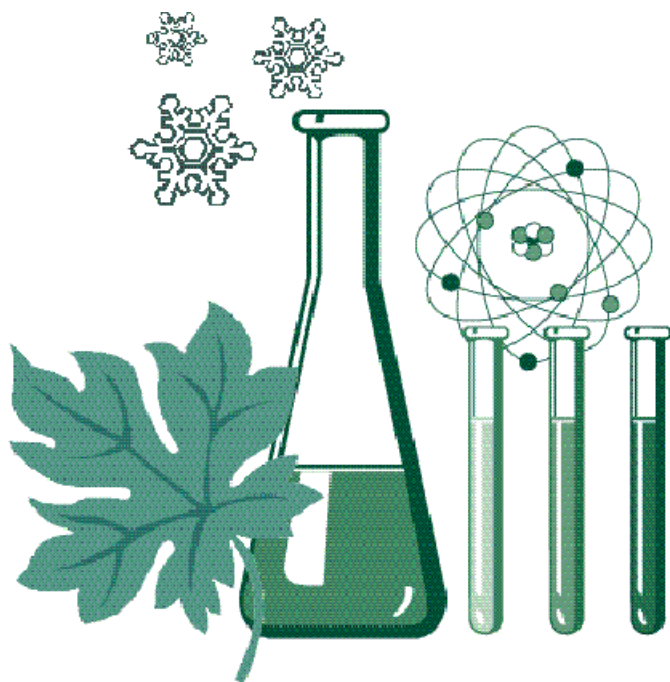
- a) static electricity, current electricity, and circuits;
- b) magnetic fields and electromagnets; and
- c) motors and generators.

Understanding the Standard

Science standards 4.3 provide students with a strong foundation in the characteristics of electricity and simple circuits. Students in fourth grade construct series and parallel circuits and make electromagnets. Standard PS.11 is intended to provide a more in-depth and mathematical focus on circuits, current, static electricity, and the relationship between electricity and magnetism. It is intended that students will actively develop scientific investigation, reasoning, and logic skills (PS.1) in the context of the key concepts presented in this standard.

Standard PS.11

Overview	Essential Knowledge, Skills, and Processes
<p>The critical scientific concepts developed in this standard include the following:</p> <ul style="list-style-type: none">• Several factors affect how much electricity can flow through a system. Resistance is a property of matter that affects the flow electricity. Some substances have more resistance than others.• Friction can cause electrons to be transferred from one object to another. These static electrical charges can build up on an object and be discharged slowly or rapidly. This is often called static electricity.• Electricity is related to magnetism. Magnetic fields can produce electrical current in conductors. Electricity can produce a magnetic field and cause iron and steel objects to act like magnets.• <i>Electromagnets</i> are temporary magnets that lose their magnetism when the electric current is removed. Both a motor and a generator have magnets (or electromagnets) and a coil of wire that creates another magnetic field.• A <i>generator</i> is a device that converts mechanical energy into electrical energy. Most of the electrical energy we use comes from generators. Electric motors convert electrical energy into mechanical energy that is used to do work. Examples of motors include those in many household appliances, such as blenders and washing machines.	<p>In order to meet this standard, it is expected that students should be able to</p> <ul style="list-style-type: none">• explain the relationship between a magnetic field and an electric current.• design an investigation to illustrate the effects of static electricity.• construct and compare series and parallel circuits.• create an electromagnet and explain how it works.• construct simple circuits to determine the relationship between voltage, resistance, and current.• compare and contrast generators and motors and how they function.• identify situations in everyday life in which motors and generators are used.



Science Standards of Learning Curriculum Framework

Earth Science

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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Standard ES.1 a, b

The student will plan and conduct investigations in which

- a) volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools; and
- b) technologies, including computers, probeware, and global positioning systems (GPS), are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions.

Essential Understandings

- *Density* expresses the relationship between mass and volume.

Essential Knowledge and Skills**Skills**

- Measure mass and volume of materials in the lab.
- Calculate density.
- Interpret data from a graph or table that shows change in mass, density, or temperature over time.
- Interpret data from a graph or table that shows changes in temperature or pressure with depth.

Standard ES.1 c, d, e

The student will plan and conduct investigations in which

- c) scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted;
- d) variables are manipulated with repeated trials; and
- e) a scientific viewpoint is constructed and defended (the nature of science).

Essential Understandings

- Information and data collected can be organized and expressed in the form of charts, graphs, and diagrams.
- Changing relevant variables will generally change the outcome.
- A hypothesis can be supported, modified, or rejected based on collected data. A *hypothesis* is a tentative explanation that accounts for a set of facts and can be tested by further investigation.
- Experiments are designed to test hypotheses.
- *Scientific laws* are generalizations of observational data that describe patterns and relationships. Laws may change as new data become available.
- *Scientific theories* are systematic sets of concepts that offer explanations for observed patterns in nature. Theories provide frameworks for relating data and guiding future research. Theories may change as new data become available.

Essential Knowledge and Skills

Skills

- Compare topographic maps of different scales.
- Construct a graph, table, chart, and/or diagram from data.
- Interpret graphs and diagrams.
- Use scientific methodology to design and test a hypothesis.
- Compare and contrast hypotheses, theories, and scientific laws. For example, students should be able to compare/contrast the Law of Superposition and the Theory of Plate Tectonics.

Standard ES.2 a, b, c, d, e

The student will demonstrate scientific reasoning and logic by

- a) analyzing how science explains and predicts the interactions and dynamics of complex Earth systems;
- b) recognizing that evidence is required to evaluate hypotheses and explanations;
- c) comparing different scientific explanations for a set of observations about the Earth;
- d) explaining that observation and logic are essential for reaching a conclusion; and
- e) evaluating evidence for scientific theories.

Essential Understandings

- Earth is a dynamic system, and all atmospheric, geological, and oceanographic processes interrelate and influence one another.
- Conclusions are only as good as the quality of the collected data.
- Any valid hypothesis can be tested.
- Any valid scientific theory has passed tests designed to invalidate it.
- A hypothesis can be supported, modified, or rejected based on collected data.
- Experiments are designed to test hypotheses.
- There can be more than one explanation for any phenomena.

Essential Knowledge and Skills

Skills

- Make predictions, using scientific data and data analysis.
- Use data to support or reject a hypothesis.
- Explain how the scientific method is used to validate scientific theories.

Standard ES.3 a, b, c, d

The student will investigate and understand how to read and interpret maps, globes, models, charts, and imagery. Key concepts include

- a) maps (bathymetric, geologic, topographic, and weather) and star charts;
- b) imagery (aerial photography and satellite images);
- c) direction and measurements of distance on any map or globe; and
- d) location by latitude and longitude and topographic profiles.

Essential Understandings

- Scale relates to actual distance.
- Topographic maps, air photos, and satellite images relate to actual 3-D landforms.
- Grid systems are used to define locations and directions on maps, globes, and charts.

Essential Knowledge and Skills

Skills

- Read and interpret maps, including legends and lines (e.g., contour and isobar).
- Locate points and directions on maps and globes, using latitude and longitude.
- Construct profiles from topographic contours.
- Determine distance and elevation on a map.
- Identify a hilltop, stream, and valley on a topographic map.

Standard ES.4 a, b

The student will investigate and understand the characteristics of the Earth and the solar system. Key concepts include

- a) position of the earth in the solar system; and
- b) sun-Earth-moon relationships (seasons, tides, and eclipses).

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Earth is one of nine planets in the solar system.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• Earth is the third planet from the sun and is located between the sun and the asteroid belt. It has one natural satellite, the moon.• Earth revolves around the sun, tilted on its axis, causing seasons (equinoxes and solstices).• The moon revolves around Earth creating the moon phases and eclipses.• Solar eclipses occur when the moon blocks sunlight from Earth's surface, while lunar eclipses occur when Earth blocks sunlight from reaching the moon's surface.• The tides are the daily, periodic rise and fall of water level caused by the gravitational pull of the sun and moon.• Water occurs on Earth as a solid (ice), a liquid, or a gas (water vapor) due to Earth's position in the solar system.

Standard ES.4 c, d

The student will investigate and understand the characteristics of the Earth and the solar system. Key concepts include

- c) characteristics of the sun, planets and their moons, comets, meteors, and asteroids; and
- d) the history and contribution of the space program.

Essential Understandings

- The solar system consists of many types of celestial bodies.
- Much of our knowledge about the solar system is a result of space exploration efforts. These efforts continue to improve our understanding of the solar system

Essential Knowledge and Skills

Knowledge

- The sun consists largely of hydrogen gas. Its energy comes from nuclear fusion of hydrogen to helium.
- There are essentially two types of planets in our solar system.
- The four inner (terrestrial) planets consist mostly of solid rock.
- Four of the outer planets are gas giants, consisting of thick outer layers of gaseous materials, perhaps with small rocky cores.
- The fifth outer planet, Pluto, has an unknown composition but appears to be solid.
- Moons are natural satellites of planets that vary widely in composition.
- Comets orbit the sun and consist mostly of frozen gases.

Standard ES.4 c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Asteroids are rocky or metallic iron objects ranging in size from millimeters to kilometers. They are the source of most meteorites.• Apollo 11 was the first manned landing on the moon.• The Hubble Space Telescope has greatly improved our understanding of the universe. <p><u>Skills</u></p> <ul style="list-style-type: none">• Draw a diagram of the solar system, and label the planets.

Standard ES.5 a, b

The student will investigate and understand how to identify major rock-forming and ore minerals based on physical and chemical properties. Key concepts include

- a) hardness, color and streak, luster, cleavage, fracture, and unique properties; and
- b) use of minerals.

Essential Understandings

- There is a difference between rocks and minerals.
- Minerals can be identified based on specific chemical and physical properties.
- Minerals are important to human wealth and welfare.

Essential Knowledge and SkillsKnowledge

- A *mineral* is a naturally occurring, inorganic, solid substance with a definite chemical composition and structure.
- Minerals may be identified by their physical properties, such as hardness, color, luster, and streak.
- Most rocks are made of one or more minerals.
- Some major rock-forming minerals are quartz, feldspar, calcite, and mica.
- Ore minerals include pyrite, magnetite, hematite, galena, graphite, and sulfur.
- The major elements found in Earth's crust are oxygen, silicon, aluminum, and iron. The most abundant group of minerals is the silicates, which contain silicon and oxygen.

Standard ES.6 a, b, c

The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include

- a) igneous (intrusive and extrusive) rocks;
- b) sedimentary (clastic and chemical) rocks; and
- c) metamorphic (foliated and unfoliated) rocks.

Essential Understandings

- Rocks can be identified on the basis of mineral content and texture.
- The processes by which rocks are formed define the three major groups of rocks.
- The *rock cycle* is the process by which all rocks are formed and how basic Earth materials are recycled through time.

Essential Knowledge and SkillsKnowledge

- Igneous rock forms from molten rock that cools and hardens either below or on Earth's surface.
- Sedimentary rocks may be formed either by rock fragments or organic matter being bound together or by chemical precipitation.
- Metamorphic rocks form when any rock is changed by the effects of heat, pressure, or chemical action.
- Extrusive igneous rocks have small or no crystals, resulting in fine-grained or glassy textures.
- Intrusive igneous rocks have larger crystals and a coarser texture.
- Extrusive igneous rocks include pumice, obsidian, and basalt.
- Intrusive igneous rocks include granite.

Standard ES.6 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Sedimentary rocks are clastic or chemical.• Clastic sedimentary rocks are made up of fragments of other rocks and include sandstone, conglomerate, and shale.• Non-clastic sedimentary rocks include limestone and rock salt.• Metamorphic rocks can be foliated or unfoliated (non-foliated).• Foliated metamorphic rocks have bands of different minerals. Slate, schist, and gneiss are foliated metamorphic rocks.• Unfoliated metamorphic rocks have little or no banding and are relatively homogenous throughout. Marble and quartzite are unfoliated metamorphic rocks. <p><u>Skills</u></p> <ul style="list-style-type: none">• Interpret the rock cycle diagram.• Classify the following rock types as igneous, metamorphic, or sedimentary: pumice, obsidian, basalt, granite, sandstone, conglomerate, shale, limestone, slate, schist, gneiss, marble, and quartzite.

Standard ES.7 a, b, c, d, e

The student will investigate and understand the difference between renewable and nonrenewable resources. Key concepts include

- a) fossil fuels, minerals, rocks, water, and vegetation;
- b) advantages and disadvantages of various energy sources;
- c) resources found in Virginia;
- d) making informed judgments related to resource use and its effects on Earth systems; and
- e) environmental cost and benefits.

Essential Understandings

- Resources are limited and are either renewable or nonrenewable.
- There are advantages and disadvantages to using any energy source.
- Virginia has many natural resources.
- Modern living standards are supported by extensive use of both renewable and nonrenewable resources.
- Extraction and use of any resource carries an environmental cost that must be weighed against economic benefit.

Essential Knowledge and SkillsKnowledge

- Renewable resources can be replaced by nature at a rate close to the rate at which they are used. Renewable resources include vegetation, sunlight, and surface water.
- Nonrenewable resources are renewed very slowly or not at all. Nonrenewable resources include coal, oil, and minerals.
- Fossil fuels are nonrenewable and may cause pollution, but they are relatively cheap and easy to use.
- In Virginia, major rock and mineral resources include coal for energy, gravel and crushed stone for road construction, and limestone for making concrete.

Skills

- Analyze the advantages and disadvantages of various energy sources.

Standard ES.8 a

The student will investigate and understand geologic processes including plate tectonics. Key concepts include

- a) how geologic processes are evidenced in the physiographic provinces of Virginia including the Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau.

Essential Understandings

- Virginia has a billion-year-long tectonic and geologic history.
- Virginia has five physiographic provinces produced by past tectonic and geologic activity.
- Each province has unique physical characteristics resulting from its geologic past.
- Geologic processes produce characteristic structures and features.

Essential Knowledge and Skills

Knowledge

- The five physiographic provinces of Virginia are Coastal Plain, Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau.
- The Coastal Plain is a flat area underlain by young, unconsolidated sediments. These layers of sediment were produced by erosion of the Appalachian Mountains and then deposited on the Coastal Plain.
- The Piedmont is an area of rolling hills underlain by mostly ancient igneous and metamorphic rocks. The igneous rocks are the roots of volcanoes formed during an ancient episode of subduction that occurred before the formation of the Appalachian Mountains.
- The Blue Ridge is a high ridge separating the Piedmont from the Valley and Ridge Province. The billion-year-old igneous and metamorphic rocks of the Blue Ridge are the oldest in the state. Some metamorphism of these rocks occurred during the formation of the Appalachian Mountains.

Standard ES.8 a (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• The Valley and Ridge province is an area with long parallel ridges and valleys underlain by ancient folded and faulted sedimentary rocks. The folding and faulting of the sedimentary rocks occurred during a collision between Africa and North America. The collision, which occurred in the late Paleozoic era, produced the Appalachian Mountains.• The Appalachian Plateau has rugged, irregular topography and is underlain by ancient, flat-lying sedimentary rocks. The area is actually a series of plateaus separated by faults. Most of Virginia's coal resources are found in the plateau province. <p><u>Skills</u></p> <ul style="list-style-type: none">• Label on a map and recognize the major features of the physiographic provinces of Virginia.

Standard ES. 8 b, c

The student will investigate and understand geologic processes including plate tectonics. Key concepts include

- b) processes (faulting, folding, volcanism, metamorphism, weathering, erosion, deposition, and sedimentation) and their resulting features; and
- c) tectonic processes (subduction, rifting and sea floor spreading, and continental collision).

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Weathering, erosion, and deposition are interrelated processes.• The core, mantle, and crust of Earth are dynamic systems, constantly in motion.• Earth's lithosphere is divided into plates that are in motion with respect to one another.• Most geologic activity (e.g., earthquakes, volcanoes, and mountain building) occurs as a result of relative motion along plate boundaries.• Plate motion occurs as a consequence of convection in Earth's mantle. Plate tectonics is driven by convection in the mantle.• There are two different types of crust — oceanic and continental — that have very different characteristics.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• <i>Weathering</i> is the process by which rocks are broken down chemically and physically by the action of water, air, and organisms.• <i>Erosion</i> is the process by which Earth materials are transported by moving water, ice, or wind.• <i>Deposition</i> is the process by which Earth materials carried by wind, water, or ice settle out and are deposited.• Earth consists of a solid, mostly iron inner core; a liquid, mostly iron outer core; a rocky, plastic mantle; and a rocky, brittle crust.• Relative plate motions and plate boundaries are convergent (subduction and continental collision), divergent (sea floor spreading), or transform.• Ocean crust is relatively thin, young, and dense.• Continental crust is relatively thick, old, and less dense.

Standard ES. 8 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Continental drift is a consequence of plate tectonics.• Hot spot volcanic activity, such as volcanic islands, is exceptional in that it is not related to plate boundaries.• Earthquake activity is associated with all plate boundaries.• Major features of convergent boundaries include collision zones (folded and thrust-faulted mountains) and subduction zones (volcanoes and trenches).• Major features of divergent boundaries include mid-ocean ridges, rift valleys, and fissure volcanoes.• Major features of transform boundaries include strike-slip faults.• A <i>fault</i> is a break or crack in Earth's crust along which movement has occurred.• Most active faults are located at or near plate boundaries. Earthquakes result when movement occurs along a fault.• When rocks are compressed horizontally, their layers may be deformed into wave-like forms called folds. This commonly occurs during continental collisions.• A volcano is an opening where magma erupts onto Earth's surface. Most volcanic activity is associated with subduction, rifting, or sea floor spreading.

Standard ES.9 a, b

The student will investigate and understand how freshwater resources are influenced by geological processes and the activities of humans. Key concepts include

- a) processes of soil development; and
- b) development of karst topography.

Essential Understandings

- Soil is formed from the weathering of rocks and organic activity.
- Karst topography is developed in areas underlain by carbonate rocks, including limestone and dolomite.

Essential Knowledge and SkillsKnowledge

- *Soil* is loose rock fragments and clay derived from weathered rock mixed with organic material.
- Karst topography includes features like caves and sinkholes.
- Karst topography forms when limestone is slowly dissolved away by slightly acidic groundwater.
- Where limestone is abundant in the Valley and Ridge province of Virginia, karst topography is common.

Standard ES.9 c, d, e, f

The student will investigate and understand how freshwater resources are influenced by geological processes and the activities of humans. Key concepts include

- c) identification of groundwater zones including the water table, zone of saturation, and zone of aeration;
- d) identification of other sources of fresh water including rivers, springs, and aquifers, with reference to the hydrologic cycle;
- e) dependence on freshwater resources and the effects of human usage on water quality; and
- f) identification of the major watershed systems in Virginia including the Chesapeake Bay and its tributaries.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• A substantial amount of water is stored in permeable soil and rock underground.• Earth's fresh water supply is finite.• Water is continuously being passed through the hydrologic cycle.• Fresh water is necessary for survival and most human activities.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• Permeability is a measure of the ability of a rock or sediment to transmit water or other liquids.• Water does not pass through impermeable materials.• Geological processes, such as erosion, and human activities, such as waste disposal, can pollute water supplies.• The three major regional watershed systems in Virginia lead to the Chesapeake Bay, the North Carolina sounds, and the Gulf of Mexico. <p><u>Skills</u></p> <ul style="list-style-type: none">• Interpret a simple groundwater diagram showing the zone of aeration, the zone of saturation, the water table, and an aquifer.

Standard ES.9 c, d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Interpret a simple hydrologic cycle diagram, including evaporation, condensation, precipitation, and runoff.• Locate the major Virginia watershed systems on a map (Chesapeake Bay, Gulf of Mexico, and North Carolina sounds).

Standard ES.10 a, d

The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils. Key concepts include

- a) traces and remains of ancient, often extinct, life are preserved by various means in many sedimentary rocks; and
- d) rocks and fossils from many different geologic periods and epochs are found in Virginia.

Essential Understandings

- Evidence of ancient, often extinct life is preserved in many sedimentary rocks.
- Fossil evidence indicates that life forms have changed and become more complex over geologic time.

Essential Knowledge and Skills

Knowledge

- A *fossil* is the remains, impression, or other evidence preserved in rock of the former existence of life.
- Some ways in which fossils can be preserved are molds, casts, and original bone or shell.
- Nearly all fossils are found in sedimentary rocks.
- In Virginia, fossils are found mainly in the Coastal Plain, Valley and Ridge, and Appalachian Plateau provinces.
- Most Virginia fossils are of marine organisms. This indicates that large areas of the state have been periodically covered by seawater.
- Paleozoic, Mesozoic, and Cenozoic fossils are found in Virginia.

Skills

- Describe how life has changed and become more complex over geologic time.

Standard ES.10 b, c

The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils. Key concepts include

- b) superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating bodies of rock; and
- c) absolute and relative dating have different applications but can be used together to determine the age of rocks and structures.

Essential Understandings

- Earth is very ancient — about 4.6 billion years old.
- The history of Earth and the ages of rocks can be investigated and understood by studying rocks and fossils.

Essential Knowledge and SkillsKnowledge

- Relative time places events in a sequence without assigning any numerical ages.
- Fossils, superposition, and crosscutting relations are used to determine the relative ages of rocks.
- Absolute time places a numerical age on an event.
- Radioactive decay is used to determine the absolute age of rocks.

Skills

- Interpret a simple geologic history diagram, using superposition and crosscutting relations.

Standard ES.11 a

The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

- a) physical and chemical changes (tides, waves, currents, sea level and ice cap variations, upwelling, and salinity variations).

Essential Understandings

- The ocean is a dynamic system in which many chemical, biological, and physical changes are taking place.

Essential Knowledge and Skills

Knowledge

- Most waves on the ocean surface are generated by wind.
- The *tides* are the daily, periodic rise and fall of water level caused by the gravitational pull of the sun and moon.
- There are large current systems in the oceans that carry warm water towards the poles and cold water towards the equator.
- Sea level falls when glacial ice caps grow and rises when the ice caps melt.
- Upwellings bring cold, nutrient-rich water from the deep ocean to the surface and are areas of rich biological activity.
- *Estuaries*, like the Chesapeake Bay, are areas where fresh and salt water mix, producing variations in salinity and high biological activity.

Standard ES.11 b, e

The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

- b) importance of environmental and geologic implications; and
- e) economic and public policy issues concerning the oceans and the coastal zone including the Chesapeake Bay.

Essential Understandings

- The oceans are environmentally and economically important.
- Human activities and public policy have important consequences for the oceans.
- The oceans' resources are finite and should be utilized with care.
- The impact of human activities, such as waste disposal, construction, and agriculture, affect the water quality within watershed systems and ultimately the ocean.

Essential Knowledge and SkillsKnowledge

- Algae in the oceans are an important source of atmospheric oxygen.
- The oceans are an important source of food and mineral resources as well as a venue for recreation and transportation.
- Pollution and over-fishing can harm or deplete valuable resources.
- Chemical pollution and sedimentation are great threats to the chemical and biological well-being of estuaries and oceans.

Skill

- Identify the effects of human activities on the oceans.

Standard ES.11 c, d

The student will investigate and understand that oceans are complex, interactive physical, chemical, and biological systems and are subject to long- and short-term variations. Key concepts include

- c) systems interactions (density differences, energy transfer, weather, and climate); and
- d) features of the sea floor (continental margins, trenches, mid-ocean ridges, and abyssal plains) as reflections of tectonic processes.

Essential Understandings

- Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior.
- The ocean is the single largest reservoir of heat at Earth's surface.
- The topography of the seafloor is at least as variable as that on the continents.

Essential Knowledge and SkillsKnowledge

- The stored heat in the ocean drives much of Earth's weather.
- The stored heat in the ocean causes climate near the ocean to be milder than climate in the interior of continents.
- Features of the sea floor that are related to plate tectonic processes include mid-ocean ridges and trenches.
- Other major topographic features of the oceans are continental shelves, continental slopes, abyssal plains, and seamounts.

Standard ES.12 a, b, c

The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include

- a) scientific evidence for atmospheric changes over geologic time;
- b) current theories related to the effects of early life on the chemical makeup of the atmosphere; and
- c) comparison of the Earth's atmosphere to that of other planets.

Essential Understandings

- The composition of Earth's atmosphere has changed over geologic time.
- Earth's atmosphere is unique in the solar system in that it contains substantial oxygen.

Essential Knowledge and SkillsKnowledge

- The early atmosphere contained little oxygen and more carbon dioxide than the modern atmosphere.
- Early photosynthetic life such as cyanobacteria (blue-green algae) consumed carbon dioxide and generated oxygen.
- It was only after early photosynthetic life generated oxygen that animal life became possible.
- Earth's atmosphere is 21 percent oxygen, 78 percent nitrogen, and 1 percent trace gases.
- The atmosphere of Venus is mostly carbon dioxide and very dense.
- The atmosphere of Mars is very thin and mostly carbon dioxide.

Standard ES.12 d, e

The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic processes, biologic processes, and human activities on its composition and dynamics. Key concepts include

- d) atmospheric regulation mechanisms including the effects of density differences and energy transfer; and
- e) potential atmospheric compositional changes due to human, biologic, and geologic activity.

Essential Understandings

- The composition of the atmosphere can change due to human, biologic, and geologic activity.

Essential Knowledge and SkillsKnowledge

- Human activities have increased the carbon dioxide content of the atmosphere.
- Man-made chemicals have decreased the ozone concentration in the upper atmosphere.
- Volcanic activity and meteorite impacts can inject large quantities of dust and gases into the atmosphere.
- The ability of Earth's atmosphere to absorb and retain heat is affected by the presence of gases like water vapor and carbon dioxide.

Skills

- Explain how volcanic activity or meteor impacts could affect the atmosphere and life on Earth.
- Explain how biologic activity, including human activities, may influence global temperature and climate.

Standard ES.13 a, b, c, d

The student will investigate and understand that energy transfer between the sun and the Earth and its atmosphere drives weather and climate on Earth. Key concepts include

- a) observation and collection of weather data;
- b) prediction of weather patterns;
- c) severe weather occurrences, such as tornadoes, hurricanes, and major storms; and
- d) weather phenomena and the factors that affect climate including radiation and convection.

Essential Understandings

- Weather and climate are different.
- Earth's surface is much more efficiently heated by the sun than is the atmosphere.
- The amount of energy reaching any given point on Earth's surface is controlled by the angle of sunlight striking the surface and varies with the seasons.
- Winds are created by uneven heat distribution at Earth's surface and modified by the rotation of Earth.
- Energy transfer between Earth's surface and the atmosphere creates the weather.
- Both weather and climate are measurable and, to a certain extent, predictable.
- Convection is the major mechanism of energy transfer in the oceans, atmosphere, and Earth's interior.
- Convection in the atmosphere is a major cause of weather.

Essential Knowledge and SkillsKnowledge

- Weather describes day-to-day changes in atmospheric conditions.
- Climate describes the typical weather patterns for a given location over a period of many years.
- Areas near the equator receive more of the sun's energy per unit area than areas nearer the poles.
- The conditions necessary for cloud formation are air at or below dew point and presence of condensation nuclei. Cloud droplets can join together to form precipitation.
- The four major factors affecting climate are latitude, elevation, proximity to bodies of water, and position relative to mountains.

Standard ES.13 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• The Coriolis effect causes deflections of the atmosphere due to the rotation of Earth. Global wind patterns result from the uneven heating of Earth by the sun and are influenced by the Coriolis effect.• Earth's major climatic zones are the polar, temperate, and tropical zones.• A <i>tornado</i> is a narrow, violent funnel-shaped column of spiral winds that extends downward from the cloud base toward Earth.• A <i>hurricane</i> is a tropical cyclone (counterclockwise movement of air) characterized by sustained winds of 120 kilometers per hour (75 miles per hour) or greater. <p><u>Skills</u></p> <ul style="list-style-type: none">• Label a diagram of global wind patterns.• Read and interpret data from a thermometer, a barometer, and a psychrometer.• Read and interpret a weather map.• Predict weather based on cloud type, temperature, and barometric pressure.

Standard ES.14 a, b, c, d, e

The student will investigate and understand scientific concepts related to the origin and evolution of the universe. Key concepts include

- a) nebulae;
- b) the origin of stars and star systems;
- c) stellar evolution;
- d) galaxies; and
- e) cosmology including the big bang theory.

Essential Understandings

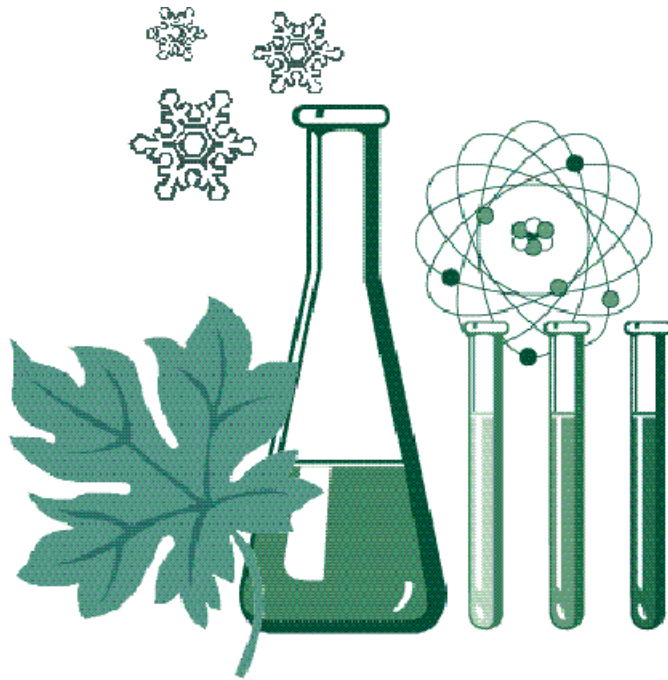
- The universe is vast and very old.
- The big bang theory is our best current model for the origin of the universe.
- The solar nebular theory is our best current idea for the origin of the solar system.
- Stars have a finite lifetime and evolve over time.
- The mass of a star controls its evolution, length of its lifetime, and ultimate fate.

Essential Knowledge and SkillsKnowledge

- The big bang theory states that the universe began in a very hot, dense state that expanded and eventually condensed into galaxies.
- The solar nebular theory explains that the planets formed through the condensing of the solar nebula.
- Stars form by condensation of interstellar gas.
- The Hertzsprung-Russell diagram illustrates the relationship between the absolute magnitude and the surface temperature of stars. As stars evolve, their position on the Hertzsprung-Russell diagram moves.
- *Galaxies* are collections of billions of stars. The basic types of galaxies are spiral, elliptical, and irregular.
- The solar system is located in the Milky Way galaxy.

Standard ES.14 a, b, c, d, e (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• A <i>light-year</i> is the distance light travels in one year and is the most commonly used measurement for distance in astronomy.• Much of our information about our galaxy and the universe comes from ground-based observations.



Science Standards of Learning Curriculum Framework

Biology

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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Standard BIO.1 a, b, c, i, j, m

The student will plan and conduct investigations in which

- a) observations of living organisms are recorded in the lab and in the field;
- b) hypotheses are formulated based on direct observations and information from scientific literature;
- c) variables are defined and investigations are designed to test hypotheses;
- i) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results;
- j) research utilizes scientific literature; and
- m) a scientific viewpoint is constructed and defended (the nature of science).

Essential Understandings

- Active participation in scientific investigations is necessary to develop an understanding of biology as an experimental science.
- The continual use and development of cognitive and manipulative skills associated with the formulation of the scientific explanations is important.
- The design of sound scientific experiments relies on systematic preliminary observations and data collected in the laboratory and in the field, as well as on a knowledge base gained from an examination of related scientific literature. Prior establishment of an adequate knowledge base is essential before hypotheses can be developed and tested.

Essential Knowledge and Skills

Skills

- Collect preliminary observations, both qualitative and quantitative.
- Make clear distinctions among observations, inferences, and predictions.
- Formulate hypotheses based on cause-and-effect relationships.
- Justify hypotheses based on both preliminary observations and scientific literature.
- Identify the independent variable (IV) and the values of the IV that will be used in the experiment.
- Select dependent variables that allow collection of quantitative data.

Standard BIO.1 a, b, c, i, j, m (continued)

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• It is typical for scientists to disagree with one another about the interpretation of evidence or a theory being considered. This is partly a result of the unique background (social, educational, etc.) that individual scientists bring to their research.• Because of this inherent subjectivity, scientific inquiry involves evaluating the results and conclusions proposed by other scientists.	<ul style="list-style-type: none">• Use appropriate technology for data collection, including probeware interfaced to a graphing calculator and/or computer, microscope, video microscope, or digital camera with image processing software.• Identify variables that must be held constant.• Establish controls as appropriate.• Write clear, replicable procedures.• Record quantitative data in clearly labeled tables with units.• Include labeled diagrams in the data record.• Critically examine and discuss the validity of results reported in scientific literature and databases.• Explain how competing scientific theories based on the same observations can be equally valid.• Recognize that in order to ensure the validity of scientific investigations, other members of the scientific community must evaluate the work.

Standard BIO.1 d, e, f, g

The student will plan and conduct investigations in which

- d) graphing and arithmetic calculations are used as tools in data analysis;
- e) conclusions are formed based on recorded quantitative and qualitative data;
- f) sources of error inherent in experimental design are identified and discussed; and
- g) validity of data is determined.

Essential Understandings

- The analysis of evidence and data is essential in order to make sense of the content of science.
- Multiple data manipulation and analysis strategies are available to help explain results of quantitative investigations.
- Data and evidence should come from a variety of sources, including student investigation, peer investigation, and databases.

Essential Knowledge and Skills**Skills**

- Determine the range, mean, and values for data, using a graphing calculator and/or computer spreadsheet software.
- Plot data graphically, showing independent and dependent variables.
- Describe linear mathematical functions from the data where appropriate, using a graphing calculator and/or computer spreadsheet.
- Discuss accuracy, confidence, and sources of experimental error based on number of trials and variance in the data.
- Recognize and discuss contradictory or unusual data.

Standard BIO.1 h, k, l

The student will plan and conduct investigations in which

- h) chemicals and equipment are used in a safe manner;
- k) differentiation is made between a scientific hypothesis and theory; and
- l) alternative scientific explanations and models are recognized and analyzed.

Essential Understandings

Essential Knowledge and Skills

Knowledge

- A hypothesis can be supported, modified, or rejected based on collected data. A *hypothesis* is a tentative explanation that accounts for a set of facts and that can be tested by further investigation. A *theory* is an explanation of a large body of information, experimental and inferential, and serves as an overarching framework for numerous concepts. It is subject to change as new evidence becomes available.

Skills

- Use evidence, apply logic, and construct an argument for conclusions based on reported data.
- Determine the extent to which data supports/does not support a hypothesis, and propose further hypotheses and directions for continued research.

Standard BIO.2 a, b, c, d

The student will investigate and understand the history of biological concepts. Key concepts include

- a) evidence supporting the cell theory;
- b) scientific explanations of the development of organisms through time (biological evolution);
- c) evidence supporting the germ theory of infectious disease; and
- d) the development of the structural model of DNA.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• In order to develop an understanding of biology as an experimental science, there must be knowledge of how scientific discoveries are made and how these discoveries have led to the accumulation of knowledge that is presented in textbooks. A historical perspective encourages the examination of concrete examples in the context from which they were developed.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• The development and refinement of magnifying lenses and light microscopes made the observation and description of microscopic organisms and living cells possible.• The development of the cell theory was accelerated by the ability to make observations on a microscopic level.• The <i>cell theory</i> states that all living things are composed of cells and that cells come from other cells by the process of cell reproduction.• Continued advances in microscopy allowed observation of cell organelles and ultrastructure. Current technology allows the observation of cellular processes underlying both cell structure and function.• Scientists have developed hypotheses about conditions on early Earth that could have led to the formation of the first organic molecules, early self-replicating molecules, the source of free oxygen in Earth's atmosphere, and the appearance of prokaryotic and later eukaryotic cells.

Standard BIO.2 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• <i>Natural selection</i> is a process by which organisms with traits well suited to an environment survive and reproduce at a greater rate than organisms less suited to that environment.• Throughout history, people have created explanations for disease.• Pasteur's and Koch's experimentation and hypotheses led to an understanding of the presence of microorganisms and their relationship to diseases.• The introduction of the germ theory led to the understanding that many diseases are caused by microorganisms.• Changes in health practices have resulted from the acceptance of the germ theory of disease.• Modern health practices emphasize sanitation, the safe handling of food and water, aseptic techniques to keep germs out of the body, and the development of vaccinations and other chemicals and processes to destroy microorganisms.• Once DNA was shown to be the genetic material, a race among scientists took place to work out its structure.• Studies of the amounts of each DNA base in different organisms led to the concept of complementary base-pairing.

Standard BIO.2 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Interpretations of X-ray photographs of DNA were used to describe the shape and dimensions of the molecule. An analysis of this and other available data led to a structural model for the DNA double helix.• The double helix model explained how heredity information is transmitted and provided the basis for an explosion of scientific research in molecular genetics.

Standard BIO.2 e

The student will investigate and understand the history of biological concepts. Key concepts include

e) the collaborative efforts of scientists, past and present.

Essential Understandings

- The scientific establishment sometimes rejects new ideas, and new discoveries often spring from unexpected findings.
- Scientific knowledge usually grows slowly through contributions from many different investigators from diverse cultures.

Essential Knowledge and SkillsKnowledge

- Science depends on experimental and observational confirmation and is subject to change as new evidence becomes available.

Standard BIO.3 a

The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

a) water chemistry and its impact on life processes.

Essential Understandings

- Water is essential for life on Earth.
- About two thirds of the mass of a cell is made up of water, and most of the biochemical processes of life occur in water solutions.

Essential Knowledge and Skills

Knowledge

- Water molecules are both cohesive and adhesive due to the nature of bonding (polar covalent and hydrogen bonding).
- Water is able to absorb large amounts of heat. As a result, lakes and oceans stabilize air and land temperatures.
- Water absorbs heat when it evaporates, allowing organisms to release excess heat.
- The solid form of water, ice, floats, preventing lakes and oceans from freezing solid.
- Water is able to dissolve many substances; therefore, the water inside and outside of cells is able to carry nutrients into and around cells and wastes away from cells.
- The pH scale ranges from 0 to 14. The pH of pure water is 7. Substances added to water can lower or raise the pH. A solution with a pH below 7 is acidic. A solution with a pH above 7 is basic.
- Organisms can tolerate only small changes in pH because every cell has a particular pH at which it functions best. For example, changes in pH cause changes in enzyme conformation, resulting in a change in activity.

Standard BIO.3 b, c

The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

- b) the structure and function of macromolecules; and
- c) the nature of enzymes.

Essential Understandings

- Most life processes are a series of chemical reactions influenced by environmental and genetic factors.
- Inside every cell is a concentrated mixture of thousands of different macromolecules forming a variety of specialized structures that carry out cell functions, such as energy production, transport, waste disposal, synthesis of new molecules, and storage of genetic material.
- Protein molecules that are assembled in cells carry out most of the cells' work. The function of each protein molecule depends on its specific conformation. The chemical reactions that occur inside cells are directly controlled by a large set of protein molecules called enzymes, whose functions depend on their specific shapes.

Essential Knowledge and Skills

Knowledge

- The main components of a living cell are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.
- Carbon atoms can easily bond to several other carbon atoms in chains and rings to form large complex molecules.
- Cells can make a variety of macromolecules from a relatively small set of monomers.
- The primary functions of carbohydrate macromolecules are to provide and store energy. The primary functions of lipid macromolecules are to insulate, store energy, and make up cell membranes.
- Nucleic acids (DNA and RNA) control cell activities by directing protein synthesis.
- Some proteins are structural (hair, nails). Others function in transport (hemoglobin), movement (muscle fibers and cytoskeletal elements), defense (antibodies), and regulation of cell functions (hormones and enzymes).

Standard BIO.3 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• <i>Proteins</i> are polymers made by linking together amino acid monomers.• A protein's structure depends on its specific conformation. The sequence of amino acids and the shape of the chain are a consequence of attractions between the chain's parts.• Each enzyme has a definite three-dimensional shape that allows it to recognize and bind with its substrate. In living cells, enzymes control the rate of metabolic reaction by acting as catalysts.• Most cells function best within a narrow range of temperature and pH. At very low temperatures, reaction rates are too slow. High temperatures or extremes of pH can irreversibly change the structure of proteins and alter their function.

Standard BIO.3 d

The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

Essential Understandings

- Plant cells and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen into the environment.
- The process of photosynthesis provides a vital connection between the sun and the energy needs of living systems.
- The breakdown of nutrient molecules enables all cells to store energy in specific chemicals that are used to carry out the life functions of the cell.

Essential Knowledge and Skills

Knowledge

- Photosynthesis and cell respiration are complementary processes for cycling carbon dioxide and oxygen as well as transferring energy in ecosystems.
- During photosynthesis, cells trap energy from sunlight with chlorophyll and use the energy, carbon dioxide and water to produce energy-rich organic molecules (glucose) and oxygen.
- During cell respiration, eukaryotic cells “burn” organic molecules with oxygen, which produces energy, carbon dioxide, and water.
- Light is the initial source of energy for most communities.
- Photosynthesis involves an energy conversion in which light energy is converted to chemical energy in specialized cells. These cells are found in autotrophs such as plants and some protists.
- Cells release the chemical energy stored in the products of photosynthesis. This energy is transported within the cell in the form of ATP.

Standard BIO.3 d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• When cells need energy to do work, certain enzymes release the energy stored in the chemical bonds in ATP. <p><u>Skills</u></p> <ul style="list-style-type: none">• Recognize the equations for photosynthesis and respiration and identify the reactants and products.

Standard BIO.4 a, b

The student will investigate and understand relationships between cell structure and function. Key concepts include

- a) characteristics of prokaryotic and eukaryotic cells; and
- b) explorations of the diversity and variation of eukaryotes.

Essential Understandings

- The cell theory is the unifying theme in biology because it emphasizes the similarity of all living things.
- The simplest life forms exhibiting cellular structure are the prokaryotes.
- Cell structure is one of the ways in which organisms differ from each other.
- The diversity that exists ranges from simple prokaryotic cells to complex multi-cellular organisms.

Essential Knowledge and Skills

Knowledge

- Earth's first cells were prokaryotes.
- Prokaryotic cells exist in two major forms: eubacteria and archaeobacteria.
- Prokaryotes are the Earth's most abundant inhabitants. They can survive in a wide range of environments and obtain energy in a variety of ways.
- Eukaryotes arose from prokaryotes and developed into larger more complex organisms, from single-celled protists to multi-cellular fungi, plants, and animals.
- Several differences between eukaryotes and prokaryotes include size, genetic material surrounded by a nuclear membrane, and the addition of mitochondria and chloroplasts.
- Cellular differences between plant and animal cells include the presence of a cell wall that gives the plant cell a defined shape, the presence of chloroplast, and the number of vacuoles.

Standard BIO.4 c, d

The student will investigate and understand relationships between cell structure and function. Key concepts include

- c) similarities between the activities of a single cell and a whole organism; and
- d) the cell membrane model (diffusion, osmosis, and active transport).

Essential Understandings

- *Cells* are the basic units of structure and function of all living things.
- Relationships between structure and function can be examined at each of the hierarchical levels of organization: molecular, cellular, organism, population, community, and ecosystem.
- Cells contain specialized structures to perform functions necessary for life.
- Cellular activities necessary for life include chemical reactions that facilitate acquiring energy, reproduction, and adaptation/maintaining homeostasis.
- Homeostasis of a cell is maintained by a plasma membrane comprised of a variety of organic molecules that controls the movement of material in and out of the cell, communication between cells, and the recognition of cells to facilitate multiple metabolic functions.

Essential Knowledge and Skills

Knowledge

- Essential cell structures and their functions include
 - the nucleus (contains DNA; site where RNA is made)
 - ribosome (site of protein synthesis)
 - mitochondria (site of cell respiration)
 - chloroplast (site of photosynthesis)
 - endoplasmic reticulum (transports materials through the cell)
 - Golgi (site where cell products are packaged for export)
 - lysosome (contains digestive enzymes)
 - cell membrane (controls what enters and leaves the cell)
 - cell wall (provides support).
- Some organisms exist as a single cell, while others are composed of many cells, each specialized to perform distinct metabolic functions.
- The basic processes necessary for living things to survive are the same for a single cell as they are for a more complex organism.

Standard BIO.4 c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• A single-celled organism has to conduct all life processes by itself. A multicellular organism has groups of cells that specialize to perform specific functions.• Cell specialization occurs during the development of a multicellular organism. The genetic information necessary for all cellular functions remains in each cell but may not be used.• The fluid mosaic model of a membrane emphasizes the arrangement and function of a bilayer of phospholipids, transport proteins, and cholesterol.• <i>Diffusion</i> occurs in cells when substances (oxygen, carbon dioxide, salts, sugars, amino acids) that are dissolved in water move from an area of higher concentration to an area of lower concentration.• <i>Osmosis</i> refers to the movement of water molecules through a semi-permeable membrane from an area of greater water concentration or pressure to an area of lesser water concentration or pressure.• <i>Active transport</i> refers to the movement of solid and liquid particles into and out of a cell by endocytosis and exocytosis.

Standard BIO.5 a, b, c

The student will investigate and understand life functions of archaebacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include

- a) how their structures and function vary between and within the kingdoms;
- b) comparison of their metabolic activities; and
- c) analyses of their responses to the environment.

Essential Understandings

- The millions of different organisms that live on Earth today share many structural and metabolic features, including cellular organization, common molecular mechanisms for energy transformation and utilization and maintenance of homeostasis, common genetic code, and mechanisms for the transmission of traits from one generation to the next.
- The diversity that is evident in the natural world can be studied in the local environment in the context of variations on a common theme.

Essential Knowledge and Skills**Skills**

- Differentiate and give examples of the following from local ecosystems:
 - autotrophs and heterotrophs (producers, consumers, and decomposers)
 - multicellular and unicellular organisms
 - motile and non-motile organisms
 - organisms with and without cell walls
 - sexually and asexually reproducing organisms
 - aquatic and terrestrial organisms
 - behavioral responses to the environment.

Standard BIO.5 d, e

The student will investigate and understand life functions of archaebacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include

- d) maintenance of homeostasis; and
- e) human health issues, human anatomy, body systems, and life functions.

Essential Understandings

- Like other organisms, human beings are composed of groups of cells (tissues, organs, and organ systems) that are specialized to provide the human organism with the basic requirements for life: obtaining food and deriving energy from it, maintaining homeostasis, coordinating body functions, and reproducing.
- Organ systems function and interact to maintain a stable internal environment that can resist disturbance from within or without (homeostasis).
- Understanding normal body functioning assists in understanding situations, both hereditary and environmental, in which functioning is impaired.

Essential Knowledge and Skills

Knowledge

- For the body to use food for energy, the food must first be digested into molecules that are absorbed and transported to cells, where the food is used for energy and for repair and growth.
- To burn food for the release of energy, oxygen must be supplied to cells and carbon dioxide removed. The respiratory system responds to changing demands by increasing or decreasing breathing rate in order to maintain homeostasis.
- The circulatory system, which moves all of these substances to or from cells, responds to changing demands by increasing or decreasing heart rate and blood flow in order to maintain homeostasis.
- The urinary system disposes of dissolved waste molecules; the intestinal tract removes solid wastes; and the skin and lungs rid the body of heat energy.

Standard BIO.5 d, e (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Specialized cells of the immune system and the molecules they produce are designed to protect against organisms and substances that enter from outside the body and against some cancer cells that arise from within.• Communication between cells is required for coordination of body functions. The nerves communicate with electrochemical signals, hormones circulate through the blood, and some cells secrete substances that spread only to nearby cells.• Environmental factors that impact human health include diet, exercise, sleep, stress, toxic substances that enter the body, viruses, and other living organisms that infect the body.• Genetic predisposition towards diseases impacts human health. Awareness of genetic predisposition allows individuals to make lifestyle changes that can enhance quality of life.

Standard BIO.5 f

The student will investigate and understand life functions of archaebacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include

f) how viruses compare with organisms.

Essential Understandings

- Viruses do not share many of the characteristics of living organisms.

Essential Knowledge and SkillsKnowledge

- Viruses are not cells. Basic viral structure consists of a nucleic acid core surrounded by a protein coat.
- Viruses can reproduce only inside a living cell, the host cell.
- The viral reproductive process includes the following steps:
 - A virus must insert its genetic material into the host cell.
 - The viral genetic material takes control of the host cell and uses it to produce viruses.
 - The newly formed viruses are released from the host cell.

Standard BIO.6 a, b, c

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- a) cell growth and division;
- b) gamete formation; and
- c) cell specialization.

Essential Understandings

- All living cells come from other living cells. During mitosis, the nucleus of the cell divides, forming two nuclei with identical genetic information.
- Many organisms are capable of combining genetic information from two parents to produce offspring. Sex cells are produced through meiosis. This allows sexually reproducing organisms to produce genetically differing offspring.
- The many body cells of an organism can be specialized to perform different functions, even though they are all descended from a single cell and contain essentially the same genetic information.

Essential Knowledge and SkillsKnowledge

- Mitosis produces two genetically identical cells.
- Meiosis occurs in sexual reproduction when a diploid germ cell produces four haploid daughter cells that can mature to become gametes (sperm or egg).
- A typical cell goes through a process of growth, development, and reproduction called the cell cycle.
- Mitosis and meiosis refer to division of the nuclear material. Cytokinesis is the division of the cytoplasm and organelles.
- Mitosis is referred to in the following stages: prophase, metaphase, anaphase, and telophase.

Standard BIO.6 d

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

d) prediction of inheritance of traits based on the Mendelian laws of heredity.

Essential Understandings

- Geneticists apply mathematical principles of probability to Mendel's laws of heredity in order to predict the results of simple genetic crosses.

Essential Knowledge and SkillsKnowledge

- Mendel's laws of heredity are based on his mathematical analysis of observations of patterns of inheritance of traits.
- The laws of probability govern simple genetic recombinations.
- Genotype describes the genetic make-up of an organism and phenotype describes the organism's appearance based on its genes.
- Homozygous individuals have two identical alleles for a particular trait, while heterozygous individuals have contrasting alleles.
- When one allele masks the effect of another, that allele is called dominant and the other recessive. When an intermediate phenotype occurs and no allele dominates, incomplete dominance results.

Standard BIO.6 d (continued)

Essential Understandings	Essential Knowledge and Skills
	<p><u>Skills</u></p> <ul style="list-style-type: none"><li>• Predict possible gametes in a dihybrid cross, given parental genotypes.<li>• Use a Punnett square to show all possible combinations of gametes and the likelihood that particular combinations will occur in monohybrid crosses.

Standard BIO.6 e

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

e) genetic variation (mutation, recombination, deletions, additions to DNA).

Essential Understandings

- Genetically diverse populations are more likely to survive changing environments.
- Recombination and mutation provide for genetic diversity.
- Some new gene combinations have little effect, some can produce organisms that are better suited to their environments, and others can be deleterious.

Essential Knowledge and Skills

Knowledge

- The sorting and recombination of genes in sexual reproduction results in a great variety of gene combinations in the offspring of any two parents.
- Inserting, deleting, or substituting DNA bases can alter genes. An altered gene may be passed on to every cell that develops from it, causing an altered phenotype.
- An altered phenotype may be beneficial or detrimental.
- Sometimes entire chromosomes can be added or deleted, resulting in a genetic disorder such as Trisomy 21 (Down syndrome).

Skill

- Evaluate karyotype charts.

Standard BIO.6 f, g

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- f) the structure, function, and replication of nucleic acids (DNA and RNA); and
- g) events involved in the construction of proteins.

Essential Understandings

- DNA stores the information for directing the construction of proteins within a cell. These proteins determine the phenotype of an organism.
- The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The code is virtually the same for all life forms.
- Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on life functions.

Essential Knowledge and Skills

Knowledge

- The genetic code is a sequence of DNA nucleotides in the nucleus of eukaryotic cells.
- DNA is a polymer consisting of nucleotides. A DNA nucleotide is identified by the base it contains: adenine (A), guanine (G), and cytosine (C) or thymine (T).
- DNA is a double-stranded molecule. The strands are connected by complementary nucleotide pairs (A-T and C-G) like rungs on a ladder. The ladder twists to form a double helix.
- The genetic code is the sequence of DNA nucleotides.
- In order for cells to make proteins, the DNA code must be transcribed (copied) to messenger RNA (mRNA).
- The mRNA carries the code from the nucleus to the ribosomes in the cytoplasm.

Standard BIO.6 f, g (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• RNA is a single-stranded polymer of four nucleotide monomers. A RNA nucleotide is identified by the base it contains: adenine (A), guanine (G), and cytosine (C) or uracil (U).• At the ribosome, amino acids are linked together to form specific proteins. The amino acid sequence is directed by the mRNA molecule.• Cells pass on their genetic code by replicating (copying) their DNA.• During DNA replication, enzymes unwind and unzip the double helix and each strand serves as a template for building a new DNA molecule. Free nucleotides bond to the template (A-T and C-G) forming a complementary strand. The final product of replication is two identical DNA molecules. <p><u>Skills</u></p> <ul style="list-style-type: none">• Given a DNA sequence, write a complementary mRNA strand (A-U, T-A, C-G and G-C).

Standard BIO.6 h, i

The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- h) use, limitations, and misuse of genetic information; and
- i) exploration of the impact of DNA technologies.

Essential Understandings

- DNA technologies allow scientists to identify, study, and modify genes.
- Genetic engineering techniques are used in a variety of industries, in agriculture, in basic research, and in medicine.

Essential Knowledge and Skills

Knowledge

- Forensic identification is an example of the application of DNA technology.
- There is great potential for the development of useful products through genetic engineering (e.g., human growth hormone, insulin, and pest- and disease-resistant fruits and vegetables).
- Eugenics, a pseudo-science of selective procreation, was a movement throughout the twentieth century, worldwide as well as in Virginia, that demonstrated a misuse of the principles of heredity.
- The Human Genome Project is a collaborative effort to map the entire gene sequence of organisms. This information will be useful in detection, prevention, and treatment of many genetic diseases.
- The potential for identifying and altering genomes raises practical and ethical questions.
- *Cloning* is the production of genetically identical cells and/or organisms.

Standard BIO.7 a

The student will investigate and understand bases for modern classification systems. Key concepts include

- a) structural similarities among organisms.

Essential Understandings

- Biological classifications are based on how organisms are related.
- Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their relationships over a period of time.
- *Species* is the basic unit of classification.
- Investigations of local flora and fauna provide opportunities to enhance understanding and stimulate interest in local environmental issues by developing and applying classification systems in the field.

Essential Knowledge and Skills

Knowledge

- Binomial nomenclature is a standard way of identifying a species with a scientific two-word name. The first word is the genus name and the second the species name.
- A *species* is defined as a group of organisms that has the ability to interbreed and produce fertile offspring.

Skills

- Construct and utilize dichotomous keys to classify groups of objects and organisms.
- Describe relationships based on homologous structures.

Standard BIO.7 b, c, d, e

The student will investigate and understand bases for modern classification systems. Key concepts include

- b) fossil record interpretation;
- c) comparison of developmental stages in different organisms;
- d) examination of biochemical similarities and differences among organisms; and
- e) systems of classification that are adaptable to new scientific discoveries.

Essential Understandings

- Information about relationships among living organisms and those that inhabited Earth in the past is gained by comparing developmental stages of organisms and by examining and interpreting the fossil record. This information is continually being gathered and used to modify and clarify existing classification systems.
- Similarities among organisms on the structural and metabolic levels are reflected in the large degree of similarity in proteins and nucleic acids of different organisms. Diversity is the product of variations in these molecules.

Essential Knowledge and Skills**Skills**

- Compare structural characteristics of an extinct organism, as evidenced by its fossil record, with present, familiar organisms.
- Recognize similarities in embryonic stages in diverse organisms in the animal kingdom, from zygote through embryo.
- Interpret a clad gram or phylogenetic tree showing evolutionary relationships among organisms.
- Describe relationships between organisms, given amino acid or nucleotide sequences.

Standard BIO.8 a

The student will investigate and understand how populations change through time. Key concepts include

- a) evidence found in fossil records.

Essential Understandings

- Although there is not a complete record of ancient life for the past 3.5 billion years, a great deal of modern knowledge about the history of life comes from the fossil record.

Essential Knowledge and Skills

Knowledge

- A *fossil* is any evidence of an organism that lived long ago.
- Scientists have used the fossil record to construct a history of life on Earth.

Skills

- Determine the relative age of a fossil given information about its position in the rock and absolute dating by radioactive decay.

Standard BIO.8 b, c, d, e

The student will investigate and understand how populations change through time. Key concepts include

- b) how genetic variation, reproductive strategies, and environmental pressures impact the survival of populations;
- c) how natural selection leads to adaptations;
- d) emergence of new species; and
- e) scientific explanations for biological evolution.

Essential Understandings

- Genetic mutations and variety produced by sexual reproduction allow for diversity within a given population.
- Many factors can cause a change in a gene over time.
- Depending on the rate of adaptation, the rate of reproduction, and the environmental factors present, structural adaptations may take millions of years to develop.

Essential Knowledge and SkillsKnowledge

- Populations are groups of interbreeding individuals that live in the same place at the same time and compete with each other for food, water, shelter, and mates.
- Populations produce more offspring than the environment can support.
- Organisms with certain genetic variations will be favored to survive and pass their variations on to the next generation.
- The unequal ability of individuals to survive and reproduce leads to the gradual change in a population, generation after generation over many generations.
- Through his observations made in the Galapagos Islands, Charles Darwin formulated a theory of how species change over time, called *natural selection*.

Standard BIO.8 b, c, d, e (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none"> • Natural selection is governed by the principles of genetics. The change frequency of a gene in a given population leads to a change in a population and may result in the emergence of a new species. • Natural selection operates on populations over many generations. • Mutations are important in how populations change over time because they result in genetic changes to the gene pool. • Adaptations sometimes arise in response to environmental pressures, for example, the development of antibiotic resistance in bacterial populations, morphological changes in the peppered moth population, the development of pesticide resistance in insect populations. • Stephen Jay Gould's idea of <i>punctuated equilibrium</i> proposes that organisms may undergo rapid (in geologic time) bursts of speciation followed by long periods of time unchanged. This view is in contrast to the traditional evolutionary view of gradual and continuous change. <p><u>Skills</u></p> <ul style="list-style-type: none"> • Differentiate between relative and absolute dating based on fossils in biological evolution.

Standard BIO.9 a

The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

- a) interactions within and among populations including carrying capacities, limiting factors, and growth curves.

Essential Understandings

- As any population of organisms grows, it is held in check by interactions among a variety of biotic and abiotic factors.

Essential Knowledge and Skills

Knowledge

- A *community* is a collection of interacting populations.
- Population growth curves exhibit many characteristics, such as initial growth stage, exponential growth, steady state, decline, and extinction.
- Limiting factors are the components of the environment that restrict the growth of populations.
- Carrying capacity is the number of organisms that can be supported by the resources in an ecosystem.
- Abiotic factors are the nonliving elements in an ecosystem, such as temperature, moisture, air, salinity, and pH. Biotic factors are all the living organisms that inhabit the environment, including predators, food sources, and competitors.
- *Symbiosis* is a close and permanent relationship between organisms of two different species. Examples include mutualism, commensalism, and parasitism.

Standard BIO.9 a (continued)

Essential Understandings	Essential Knowledge and Skills
	<p><u>Skills</u></p> <ul style="list-style-type: none"><li>• Graph and interpret a population growth curve.

Standard BIO.9 b, c

The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

- b) nutrient cycling and energy flow through ecosystems; and
- c) succession patterns in ecosystems.

Essential Understandings

- Ecosystems demonstrate an exchange of energy and nutrients among inhabiting organisms.
- The gradual change in an ecosystem that occurs as communities slowly replace one another is known as *ecological succession*.

Essential Knowledge and SkillsKnowledge

- An *ecosystem* consists of all the interacting species and the abiotic environment in a given geographic area.
- Nutrients cycle through an ecosystem. The most common examples of such nutrients include carbon, oxygen, nitrogen, and water.
- Flow of energy occurs between trophic levels in all ecosystems and can be depicted as follows:
 - food chain
 - food web
 - pyramid of energy
 - pyramid of biomass
 - pyramid of numbers.
- *Ecological succession* is a series of changes in a community in which new populations of organisms gradually replace existing ones.

Standard BIO.9 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• A <i>climax community</i> occurs when succession slows down and a stable community is established. The climax community is made up of organisms that are successful at competing for resources in a given environment. The climax community in most of Virginia is a deciduous oak-hickory (hardwood) forest. <p><u>Skills</u></p> <ul style="list-style-type: none">• Given an illustration of a food chain and a food web, describe each organism as a producer (autotroph), consumer (primary/second order), or decomposer.

Standard BIO.9 d, e

The student will investigate and understand dynamic equilibria within populations, communities, and ecosystems. Key concepts include

- d) the effects of natural events and human activities on ecosystems; and
- e) analysis of the flora, fauna, and microorganisms of Virginia ecosystems including the Chesapeake Bay and its tributaries.

Essential Understandings

- As the human population increases, so does human impact on the environment.
- Investigations of local ecosystems provide opportunities for students to enhance their understanding and stimulate their interest in local environmental issues by applying ecological principles in the field.

Essential Knowledge and SkillsKnowledge

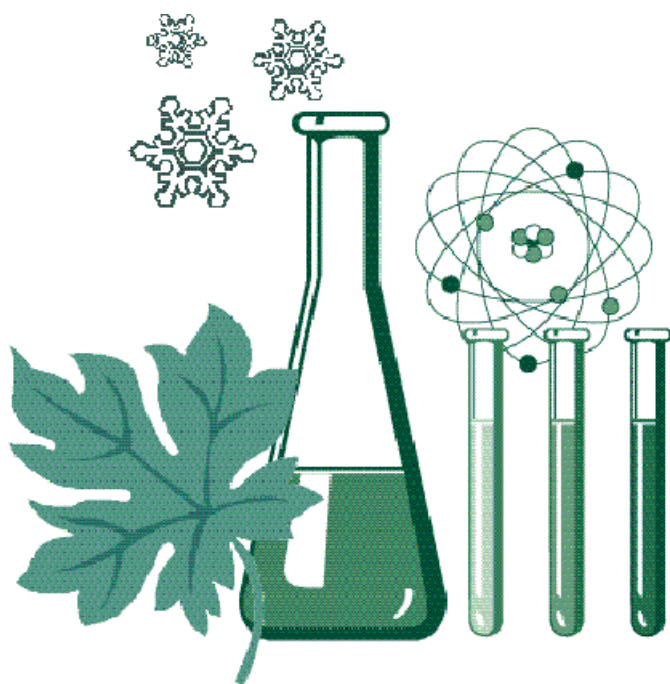
- Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the Earth's land, oceans, and atmosphere.
- Some of these changes have decreased the capacity of the environment to support some life forms.

Skills

- Observe and identify flora and fauna in a local community, using field guides and dichotomous keys for identifying and describing organisms that characterize the local ecosystem.

Standard BIO.9 d, e (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Identify and describe an ecosystem in terms of the following:<ul style="list-style-type: none">- effects of biotic and abiotic components- examples of interdependence- evidence of human influences- energy flow and nutrient cycling- diversity analysis- ecological succession.



Science Standards of Learning Curriculum Framework

Chemistry

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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Standard CH.1 a, b, c

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

- a) designated laboratory techniques;
- b) safe use of chemicals and equipment; and
- c) proper response to emergency situations.

Essential Understandings

- Measurements of quantity include length, volume, mass, temperature, time, and pressure to the correct number of significant digits.
- Techniques for experimentation involve the identification and the proper use of chemicals, the description of equipment, and the recommended statewide framework for high school laboratory safety.
- Measurements are useful in gathering data about chemicals and how they behave.

Essential Knowledge and Skills**Skills**

- Make the following measurements, using the specified equipment:
 - volume: graduated cylinder, pipette, volumetric flask, buret
 - mass: electronic or dial-a-gram
 - temperature: thermometer and/or temperature probe
 - pressure: barometer or pressure probe.
- Identify, locate, and know how to use laboratory safety equipment, including aprons, goggles, gloves, fire extinguishers, fire blanket, safety shower, eye wash, broken glass container, and fume hood.
- Demonstrate the following basic lab techniques: filtering, decanting, using chromatography, and lighting a gas burner.

Standard CH.1 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Identify the following basic lab equipment: beaker, flask, graduated cylinder, test tube, test tube rack, test tube holder, ring stand, wire gauze, clay triangle, crucible with lid, evaporation dish, watch glass, wash bottle, and dropping pipette.• Understand Material Safety Data Sheet (MSDS) warnings, including handling chemicals, lethal dose (LD), hazards, disposal, and chemical spill cleanup.• Demonstrate safe laboratory practices, procedures, and techniques.

Standard CH.1 d, e

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

- d) manipulation of multiple variables, using repeated trials; and
- e) accurate recording, organization, and analysis of data through repeated trials.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Repeated trials during experimentation ensure verifiable data.• Data tables are used to record and organize measurements.• Graphs are used to summarize the relationship between the independent and dependent variable.	<p><u>Skills</u></p> <ul style="list-style-type: none">• Design and perform experiments to test predictions.• Identify variables.• Predict outcome(s) when a variable is changed.• Record data, using the significant digits of the measuring equipment.• Demonstrate precision (reproducibility) in measurement.• Recognize accuracy in terms of closeness to the true value of a measurement.

Standard CH.1 f, g

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

- f) mathematical and procedural error analysis; and
- g) mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis).

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Measurements must be expressed in SI units.• Scientific notation is used to write very small and very large numbers.• Algebraic equations represent relationships between dependent and independent variables.• Graphed data give a picture of a relationship.• Ratios and proportions are used in calculations.• <i>Significant digits</i> of a measurement are the number of known digits together with one estimated digit.• The last digit of any valid measurement must be estimated and is therefore uncertain.• <i>Dimensional analysis</i> is a way of translating a measurement from one unit to another unit.• Graphing calculators can be used to manage the mathematics of chemistry.• Mathematical procedures are used to validate data.	<p><u>Skills</u></p> <ul style="list-style-type: none">• Discover and eliminate procedural errors.• Know most frequently used SI prefixes and their values (milli-, centi-, deci-, kilo-).• Demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place.• Correctly utilize the following when graphing data:<ul style="list-style-type: none">- dependent variable (vertical axis)- independent variable (horizontal axis)- scale and units of a graph- regression line (best fit curve).• Calculate mole ratios, percent composition, conversions, and relative atomic mass.• Use the rules for performing operations with significant digits.• Utilize dimensional analysis.

Standard CH.1 f, g (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Use graphing calculators correctly.• Read a measurement from a graduated scale, stating measured digits plus the estimated digit.• Use data collected to calculate percent error.• Determine the mean of a set of measurements.

Standard CH.1 h, i

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include

- h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data and communicating results; and
- i) construction and defense of a scientific viewpoint (the nature of science).

Essential Understandings

- Constant reevaluation in the light of new data is essential to keeping scientific knowledge current. In this fashion, all forms of scientific knowledge remain flexible and may be revised as new data and new ways of looking at existing data become available.

Essential Knowledge and Skills

- Use appropriate technology for data collection and analysis, including probeware interfaced to a graphing calculator and/or computer.
- Use probeware to gather data.
- Explain the emergence of modern theories based on historical development. For example, students should be able to explain the origin of the atomic theory beginning with the Greek atomists and continuing through the most modern Quantum models.

Standard CH.2 a, b, c

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- a) average atomic mass, mass number, and atomic number;
- b) isotopes, half lives, and radioactive decay; and
- c) mass and charge characteristics of subatomic particles.

Essential Understandings

- The periodic table is arranged in order of increasing atomic numbers.
- The atomic number of an element is the same as the number of protons.
- In a neutral atom, the number of electrons is the same as the number of protons.
- All atoms of an element have the same number of protons.
- The atomic mass for each element is the weighted average of that element's naturally occurring isotopes.

Essential Knowledge and Skills

Knowledge

- *Electrons* have little mass and a negative (–) charge. They are located in electron clouds or probability clouds outside the nucleus.
- *Protons* have a positive (+) charge. *Neutrons* have no charge. Protons and neutrons are located in the nucleus of the atom and comprise most its mass.
- An *isotope* is an atom that has the same number of protons as another atom of the same element but has a different number of neutrons. Some isotopes are radioactive; many are not.
- *Half-life* is the length of time required for half of a given sample of a radioactive isotope to decay.

Standard CH.2 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<p><u>Skills</u></p> <ul style="list-style-type: none"><li>• Using a periodic chart, determine the atomic number, atomic mass, the number of protons, the number of electrons, and the number of neutrons of any neutral atom of a particular element.<li>• Determine the half-life of a radioactive substance.<li>• Describe alpha, beta, and gamma radiation with respect to penetrating power, shielding, and composition.

Standard CH.2 d, e, f

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- d) families or groups;
- e) series and periods; and
- f) trends including atomic radii, electronegativity, shielding effect, and ionization energy.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• <i>Periodicity</i> is regularly repeating patterns or trends in the chemical and physical properties of the elements arranged in the periodic table.• Horizontal rows called <i>periods</i> have predictable properties based on an increasing number of electrons in the outer orbitals.• Vertical columns called <i>groups</i> have similar properties because of their similar valence electron configurations.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• The Periodic Law states that when elements are arranged in order of increasing atomic numbers, their physical and chemical properties show a periodic pattern.• The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, noble gases, and metalloids.• Periods and groups are named by numbering columns and rows.• Some elements, such as oxygen, hydrogen, fluorine, chlorine, bromine, and nitrogen, naturally occur as diatomic molecules.• Electronegativity increases from left to right within a period and decreases from top to bottom within a group.• Shielding effect is constant within a given period and increases within given groups from top to bottom.

Standard CH.2 d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Atomic radius decreases from left to right and increases from top to bottom within given groups.• Ionization energies generally increase from left to right and decrease from top to bottom of a given group. <p><u>Skills</u></p> <ul style="list-style-type: none">• Use an element's electron configuration to determine the number of valence electrons and possible oxidation numbers.

Standard CH.2 g

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

g) electron configurations, valence electrons, and oxidation numbers.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Electron configuration is the arrangement of electrons around the nucleus of an atom based on their energy level.• Atoms can gain, lose, or share electrons within the outer energy level.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• Electrons are added one at a time to the lowest energy levels first (Aufbau Principle).• An orbital can hold a maximum of two electrons (Pauli Exclusion Principle).• Electrons occupy equal-energy orbitals so that a maximum number of unpaired electrons results (Hund's Rule).• Energy levels are designated 1–7. Orbitals are designated s, p, d, and f according to their shapes• s, p, d, f orbitals relate to the regions of the Periodic Table.• Loss of electrons from neutral atoms results in the formation of an ion with a positive charge (cation).• Gain of electrons by a neutral atom results in the formation of an ion with a negative charge (anion).• Transition metals can have multiple oxidation states.

Standard CH.2 h

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

h) chemical and physical properties.

Essential Understandings

- Matter is classified by its chemical and physical properties.
- *Physical properties* refer to the condition or quality of a substance that can be observed or measured without changing the substance's composition.
- *Chemical properties* refer to the ability of a substance to undergo chemical reaction and form a new substance.

Essential Knowledge and Skills

Knowledge

- Matter occurs as elements (pure), compounds (pure), and mixtures, which may be homogeneous (solutions) or heterogeneous.
- Important physical properties are density, conductivity, melting point, boiling point, malleability, and ductility.
- *Reactivity* is the tendency of an element to enter into a chemical reaction.

Standard CH.2 i

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- i) historical and quantum models.

Essential Understandings

- Discoveries and insights related to the atom's structure have changed the model of the atom over time.
- The modern atomic theory is called the Quantum Mechanical Model.

Essential Knowledge and Skills

Knowledge

- Major insights regarding the atomic model of the atom and principal scientists include:
 - particles – Democritus
 - first atomic theory of matter – John Dalton
 - discovery of the electron – J. J. Thompson
 - discovery of the nucleus – Ernest Rutherford
 - discovery of charge of electron – Robert Millikan
 - planetary model of atom – Niels Bohr
 - periodic table by atomic mass – Demitry Mendeleev
 - periodic table by atomic number – Henry Moseley
 - quantum nature of energy – Max Planck
 - uncertainty principle – Werner Heisenberg
 - wave theory – Louis de Broglie.

Standard CH.3 a, b, c, d

The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- a) nomenclature;
- b) balancing chemical equations;
- c) writing chemical formulas (molecular, structural, and empirical; and Lewis diagrams); and
- d) bonding types (ionic and covalent).

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Conservation of matter is represented in balanced chemical equations.• Chemical formulas are used to represent compounds.• <i>Subscripts</i> represent the relative number of each type of atom in a molecule or formula unit.• A <i>coefficient</i> is a quantity that precedes a reactant or product symbol or formula in a chemical equation and indicates the relative number of particles involved in the reaction.• Bonds form between atoms to achieve stability.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• When pairs of elements form two or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios (Law of Multiple Proportions).• The <i>empirical formula</i> shows the simplest whole-number ratio in which the atoms of the elements are present in the compound.• The <i>molecular formula</i> shows the actual number of atoms of each element in one molecule of the substance.• <i>Structural formulas</i> also show the arrangements of atoms and bonds.• <i>Covalent bonds</i> involve the sharing of electrons.• <i>Ionic bonds</i> involve the transfer of electrons.

Standard CH.3 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• <i>Ionization energy</i> is the energy required to remove the most loosely held electron from a neutral atom. Elements with low ionization energy form positive ions (cations) easily. Elements with high ionization energy form negative ions (anions) easily.• <i>Electronegativity</i> is the measure of the attraction of an atom for electrons in a covalent bond.• <i>Polar molecules</i> result when a molecule behaves as if one end were positive and the other end negative.• The IUPAC system is used for naming compounds. <p><u>Skills</u></p> <ul style="list-style-type: none">• Name binary covalent compounds.• Name binary ionic compounds (using the Roman numeral system where appropriate).• Predict, draw, and name molecular shapes (bent, linear, trigonal planar, tetrahedral, and trigonal pyramidal).• Determine formulas, write equations, and balance chemical equations.• Write the chemical formulas for certain common substances, such as ammonia, water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetrafluoride.

Standard CH.3 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Recognize the formulas and names of certain polyatomic ions, such as carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium, and use these polyatomic ions for naming and writing the formulas of ionic compounds.• Draw Lewis Dot Diagrams to show covalent bonding.

Standard CH.3 e, f

The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- e) reaction types (synthesis, decomposition, single and double replacement, oxidation-reduction, neutralization, exothermic, and endothermic); and
- f) reaction rates and kinetics (activation energy, catalysis, and degree of randomness).

Essential Understandings

- Elements and compounds react in different ways.
- Spontaneous reactions may be fast or slow.
- Randomness (entropy), heat content (enthalpy), and temperature affect spontaneity.
- Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy).

Essential Knowledge and Skills

Knowledge

- Major types of chemical reactions are
 - synthesis ($A+B \rightarrow AB$)
 - decomposition ($BC \rightarrow B+C$)
 - single replacement ($A+BC \rightarrow B+AC$)
 - double replacement ($AC+BD \rightarrow AD+BC$).
- Chemical reactions based on the net heat energy are exothermic reaction (heat producing) and endothermic reaction (heat absorbing).
- Reactions can occur in two directions simultaneously.
- Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.
- Catalysts decrease the amount of activation energy needed.

Standard CH.3 e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	<p><u>Skills</u></p> <ul style="list-style-type: none"><li>• Recognize equations for redox reactions and neutralization reactions.<li>• Interpret reaction rate diagrams.

Standard CH.4 a, b

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- a) Avogadro's principle and molar volume; and
- b) stoichiometric relationships.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Atoms and molecules are too small to count by usual means.• A <i>mole</i> is a way of counting any type of particle (atoms, molecules, and formula units).• Stoichiometry involves quantitative relationships.• Stoichiometric relationships are based on mole quantities in a balanced equation.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• Avogadro's number = 6.02×10^{23} particles per mole.• Molar volume = $22.4 \text{ dm}^3/\text{mole}$ and/or 22.4 L/mole for any gas at STP.• Molar mass of a substance is its average atomic mass in grams from the Periodic Table.• Total grams of reactant(s) = total grams of product(s). <p><u>Skills</u></p> <ul style="list-style-type: none">• Make calculations involving the following relationships:<ul style="list-style-type: none">- mole-mole;- mass-mass;- mole-mass;- mass-volume;- mole-volume; and- volume-volume.• Identify the limiting reactant (reagent) in a reaction.• Calculate percent yield of a reaction.

Standard CH.4 c, d, e, f

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- c) partial pressure;
- d) gas laws;
- e) solution concentrations; and
- f) chemical equilibrium.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Gases have mass and occupy space.• Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers.• Gas molecules with the lightest mass travel fastest.• Relatively large distances separate gas particles from each other.• An Ideal Gas does not exist, but this concept is used to model gas behavior.• A Real Gas exists, has intermolecular forces and particle volume, and can change states.• Equal volumes of gases at the same temperature and pressure contain an equal number of particles.• Solutions can be a variety of solute/solvent combinations: gas/gas, gas/liquid, liquid/liquid, solid/liquid, gas/solid, liquid/solid, or solid/solid.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• The pressure and volume of a sample of a gas at constant temperature are inversely proportional to each other (Boyle's Law).• At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law).• The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton's law of partial pressures).• Ideal Gas Law states that $PV = nRT$.• Molarity = moles/dm³ or moles/L of solution.• Pressure Units include K Pa and mm of Hg. <p><u>Skills</u></p> <ul style="list-style-type: none">• Solve problems and interpret graphs involving the gas laws.

Standard CH.4 g

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- g) acid/base theory: strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

Essential Understandings

- Two important classes of compounds are acids and bases.
- Acids and bases are defined by several theories.
- Acids and bases dissociate in varying degrees.

Essential Knowledge and Skills

Knowledge

- Arrhenius acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. Arrhenius bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue.
- Bronsted-Lowry-acids are proton donors, whereas bases are proton acceptors.
- The pH number denotes hydrogen (hydronium) ion concentration. The pOH number denotes hydroxide ion concentration.
- $\text{pH} + \text{pOH} = 14$
- pH is a number scale ranging from 0 to 14 that represents the acidity of a solution.
- [] refers to molar concentration.
- Strong acid-strong base titration is the process that measures $[\text{H}^+]$ and $[\text{OH}^-]$.
- Indicators show color changes at certain pH levels.
- Strong electrolytes dissociate completely. Weak electrolytes dissociate partially.

Standard CH.5 a, b

The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- a) pressure, temperature, and volume; and
- b) vapor pressure.

Essential Understandings

- Atoms and molecules are in constant motion.
- The Kinetic Molecular Theory is a model for predicting and explaining gas behavior.
- Forces of attraction between molecules determine the physical changes of state.
- Vapor pressure is a property of a substance determined by intermolecular forces.

Essential Knowledge and SkillsKnowledge

- Pressure, temperature, and volume changes can cause a change in physical state.
- Forces of attraction include hydrogen bonding, dipole-dipole attraction, and London dispersion (van der Waals) forces.

Standard CH.5 c, d, e, f

The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- c) phase changes;
- d) molar heats of fusion and vaporization;
- e) specific heat capacity; and
- f) colligative properties.

Essential Understandings

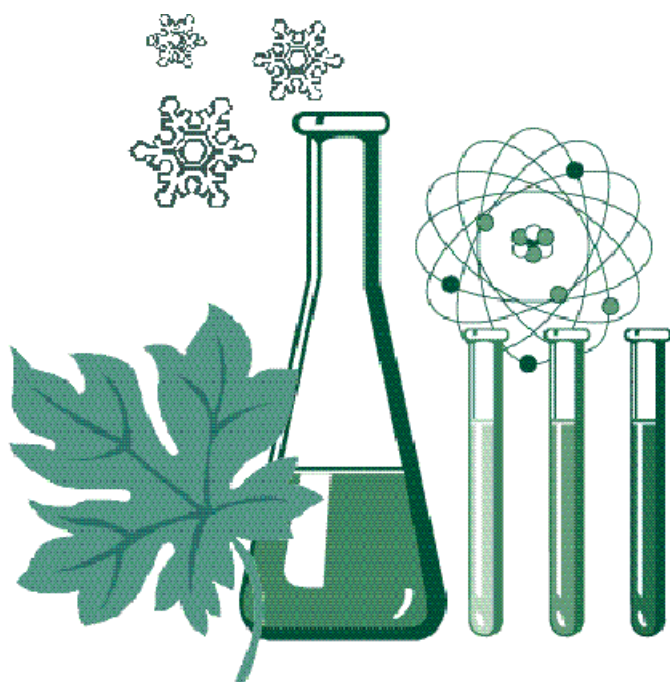
- Solid, liquid, and gas phases of a substance have different energy content.
- Specific amounts of energy are absorbed or released during phase changes.
- Specific heat capacity is a property of a substance.
- Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances.
- The number of solute particles changes the freezing point and boiling point of a pure substance.

Essential Knowledge and SkillsKnowledge

- A liquid's boiling point and freezing point are affected by changes in atmospheric pressure.
- A liquid's boiling point and freezing point are affected by the presence of certain solutes.

Skills

- Graph and interpret a heating curve (temperature vs. time).
- Calculate energy changes, using specific heat capacity.
- Calculate energy changes, using molar heat of fusion and molar heat of vaporization.
- Interpret a phase diagram of water.
- Perform calorimetry calculations.
- Recognize polar molecules and non-polar molecules.



Science Standards of Learning Curriculum Framework

Physics

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Standard PH.1 a, b, e

The student will plan and conduct investigations in which

- a) the components of a system are defined;
- b) instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge; and
- e) the limitations of the experimental apparatus and design are recognized.

Essential Understandings

- Appropriate instruments are used to measure displacement, time, mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge.
- No measurement is complete without a statement about its exactness.

Essential Knowledge and SkillsKnowledge

- The difference between the accepted value and the measured value is the uncertainty or error.

Skills

- Determine percent error from experimental and theoretical values.
- Measure displacement, time, mass, volume, temperature, heat exchange, energy transformations, motion, and electric charge.
- Follow safe practices in all laboratory procedures.

Standard PH.1 c, d, f, g, h

The student will plan and conduct investigations in which

- c) information is recorded and presented in an organized format;
- d) metric units are used in all measurements and calculations;
- f) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges;
- g) data gathered from non-SI instruments are incorporated through appropriate conversions; and
- h) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• Experimental records, including experimental diagrams, data, and procedures, are kept concurrently with experimentation.• Tables and graphs are used to interpret, organize, and clarify experimental observations, possible explanations, and models for phenomena being observed.• The average for a set of data is a valid way to estimate the true value of the set.• The spread in a set of data is an indication of the error in the measurement: a large spread indicates a large error, and a small spread indicates a small error.	<p><u>Knowledge</u></p> <ul style="list-style-type: none">• Measurements are always recorded with appropriate SI units.• Calculations are made using appropriate SI units.• Results of calculations or analyses of data are reported in appropriate numbers of significant digits.• Data are organized into tables and graphed when involving dependent and independent variables. <p><u>Skills</u></p> <ul style="list-style-type: none">• Calculate average values, and compare to theoretical values.

Standard PH.2 a, b, c, d

The student will investigate and understand how to analyze and interpret data. Key concepts include

- a) a description of a physical problem is translated into a mathematical statement in order to find a solution;
- b) relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;
- c) the slope of a linear relationship is calculated and includes appropriate units; and
- d) interpolated, extrapolated, and analyzed trends are used to make predictions.

Essential Understandings

- Mathematics is a tool used to explain and describe phenomena.
- Dimensional analysis is the verification of the appropriateness of the units. (This can be used as a consistency check in calculations as well as in experiments.)
- Graphing is used to reveal relationships and other important features of data.
- Predictions are made from trends based on the data.
- All experimental data do not follow a linear relationship.

Essential Knowledge and Skills

Knowledge

- The shape of the curve passing through experimentally obtained data is used to determine the relationship of the plotted quantities.
- A physical phenomena or events can often be described in mathematical terms (as an equation or inequality).

Skills

- Recognize linear and nonlinear relationships from graphed data.
- Draw the appropriate straight line through a set of experimental data points and determine the slope, using appropriate SI units.
- Use dimensional analysis to solve problems.

Standard PH.2 e

The student will investigate and understand how to analyze and interpret data. Key concepts include

e) analysis of systems employs vector quantities utilizing trigonometric and graphical methods.

Essential Understandings

- Not all quantities add algebraically. Some must be combined using trigonometry. These quantities are known as vectors.

Essential Knowledge and Skills**Skills**

- Combine vectors and resolve vectors into components, using graphical methods that place scaled vectors head-to-tail.
- Sketch a vector diagram, and trigonometrically solve for the components.
- Sketch the components of a vector, and trigonometrically solve for the resultant.

Standard PH.3 a, b, c, d, e

The student will investigate and understand how to demonstrate scientific reasoning and logic. Key concepts include

- a) analysis of scientific sources to develop and refine research hypotheses;
- b) analysis of how science explains and predicts relationships;
- c) evaluation of evidence for scientific theories;
- d) examination of how new discoveries result in modification of existing theories or establishment of new paradigms; and
- e) construction and defense of a scientific viewpoint (the nature of science).

Essential Understandings

- Experimentation may support a hypothesis, falsify it, or lead to new discoveries.
- The hypothesis may be modified based upon data and analysis.
- A careful study of prior reported research is a basis for the formation of a research hypothesis.
- A *theory* is a comprehensive and effective explanation, which is well supported by experimentation and observation, of a set of phenomena..
- Science is a human endeavor relying on human qualities, such as reasoning, insight, energy, skill, and creativity as well as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

Essential Knowledge and SkillsKnowledge

- Relativity and quantum mechanics are recent examples of paradigm shifts in theoretical physics.
- The change from an earth-centered to a sun-centered model of the solar system is an example of a paradigm shift.

Skills

- Identify and explain the interaction between human nature and the scientific process.

Standard PH.4 a, b

The student will investigate and understand how applications of physics affect the world. Key concepts include

- a) examples from the real world; and
- b) exploration of the roles and contributions of science and technology.

Essential Understandings

- Physics discoveries, both theoretical and experimental, result in advancements in communication, medicine, transportation, commerce, exploration, and technology.

Essential Knowledge and SkillsKnowledge

- Journals, books, the Internet, and other sources are used in order to identify key contributors and their contributions to physics as well as their impact on the real world.

Standard PH.5 a, b, c

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

- a) linear motion;
- b) uniform circular motion; and
- c) projectile motion.

Essential Understandings

- Linear motion graphs include
 - displacement (d) vs. time (t)
 - velocity (v) vs. time (t)
 - acceleration (a) vs. time (t)
- Position, displacement, velocity, and acceleration are vector quantities.
- The concept of motion is described in terms of position, displacement, velocity, acceleration, and their dependence on time.
- Graphical analysis is used as a representation of motion.
- Horizontal and vertical components of the motion of a projectile are independent of one another.
- In a uniform vertical gravitational field with negligible air resistance, a projectile moves with constant horizontal velocity and constant vertical acceleration.

Essential Knowledge and Skills

Knowledge

- *Velocity* is the change in distance divided by the change in time.
- A straight-line, position-time graph indicates constant velocity.
- A straight-line, velocity-time graph indicates constant acceleration.
- A horizontal-line, velocity-time graph indicates zero acceleration.
- The slope of a distance-time graph is the velocity.
- The slope of a velocity-time graph is the acceleration.
- *Acceleration* is the change in velocity divided by the change in time.

Standard PH.5 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
<ul style="list-style-type: none">• An object moving uniformly along a circle moves with a constant speed and with acceleration directed toward the center of the circle.• Centripetal force is a “true” force acting on a body in circular motion while centrifugal force is a “false” force that describes the feeling experienced in centripetal acceleration.	<p><u>Skills</u></p> <ul style="list-style-type: none">• Construct and analyze displacement (d) vs. time (t), velocity (v) vs. time (t), and acceleration (a) vs. time (t) graphs.• Solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration).• Resolve vector diagrams involving distance and velocity.• Draw vector diagrams of a projectile’s motion. Find range, trajectory, height of the projectile, and time of flight (uniform field, no air resistance).• Distinguish between centripetal and centrifugal force.

Standard PH.5 d, e, f

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

- d) Newton's laws of motion;
- e) gravitation; and
- f) planetary motion.

Essential Understandings

- Newton's three laws of motion are the basis for understanding the mechanical universe.
- Newton's Law of Universal Gravitation describes the force that determines the motion of celestial objects.
- The total force on a body can be represented as a vector sum of constituent forces.

Essential Knowledge and SkillsKnowledge

- An object with no force acting on it moves with constant velocity.
- The acceleration of a body is directly proportional to the net force on it and inversely proportional to its mass.
- When one object exerts a force on a second object, the second exerts a force on the first that is equal in magnitude but opposite in direction.
- *Weight* is the gravitational force acting on a body.
- ($F_w = mg$)
- *Friction* is a force that acts in a direction opposite the velocity.
- For small angles of oscillation, a pendulum exhibits simple harmonic motion.

Standard PH.5 d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	<ul style="list-style-type: none">• Newton's Law of Universal Gravitation can be used to determine the force between objects separated by a known distance, and the distance between objects with a known gravitational attraction. <p><u>Skills</u></p> <ul style="list-style-type: none">• Qualitatively explain motion in terms of Newton's Laws.• Solve problems involving force (F), mass (m), and acceleration (a).• Solve problems related to free-falling objects, including 2-D motion.• Solve problems using Newton's Law of Universal Gravitation• Solve problems using the coefficient of friction.• Solve problems involving multiple forces, using free-body diagrams.

Standard PH.5 g

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

g) work, power, and energy.

Essential Understandings

- *Energy* is the capacity to do work. Work and energy are expressed in the same units, but are not identical.
- When work is done, energy converts from one form to another and energy is conserved.

Essential Knowledge and Skills

Knowledge

- *Work* is the product of the force exerted on an object and the distance the object moves in the direction of the force.
- *Power* is the rate of doing work.
- Work and energy are measured in Joules, which is a derived unit equal to a Nm or kgm^2/s^2 .
- Power is measured in Watts, which is a derived unit equal to a J/s .

Skills

- Solve problems involving work, power, and energy.

Standard PH.6 a, b

The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include

- a) kinetic and potential energy; and
- b) elastic and inelastic collisions.

Essential Understandings

- *Kinetic energy* is energy of motion.
- *Potential energy* is energy due to an object's position or state.
- For elastic collisions, total momentum and total kinetic energy are conserved.
- For inelastic collisions, total momentum is conserved and some kinetic energy is transformed to other forms of energy, such as heat.
- Quantities such as energy and momentum are conserved when they are exchanged or transformed, and their total quantity remains the same.

Essential Knowledge and Skills**Skills**

- Calculate potential and kinetic energy from theoretical and experimental situations.
- Model conservation of energy and momentum, using elastic and inelastic collisions.

Standard PH.6 c

The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include

c) electric power.

Essential Understandings

- Electrical charge moves through electrical circuits and is conserved.

Essential Knowledge and SkillsKnowledge

- *Electric power* (watt) is change in electrical energy divided by corresponding change in time.
- *Current* (ampere) is the amount of charge that moves through a circuit element divided by the elapsed time.
- *Electric potential difference* (voltage) is change in electric potential energy per unit charge.
- In any system of electrical charge, electrical movement, or electrical interaction, both charge and energy are conserved.

Standard PH.7 a, b, c, d, e, f

The student will investigate and understand properties of fluids. Key concepts include

- a) density and pressure;
- b) variation of pressure with depth;
- c) Archimedes' principle of buoyancy;
- d) Pascal's principle;
- e) fluids in motion; and
- f) Bernoulli's principle.

Essential Understandings

- Density of solids and liquids is measured using the same units.
- The pressure of a fluid depends on the depth of the fluid and not on the shape or size of the container.
- In a moving fluid, internal pressure and speed are inversely related.
- Floating objects displace a volume of fluid that has a weight equal to the floating object.
- Submerged objects displace a volume of fluid equal to the volume of the submerged object.
- The buoyant force on an object is equal to the weight of the fluid displaced by that object.

Essential Knowledge and Skills**Skills**

- Determine if a given object will float or sink in water, given its mass and volume or dimensions.
- Explain phenomenon applying the appropriate principle.
 - the flight of a curve ball
 - the flight of a golf ball
 - the factors that allow airplanes to fly
 - the fact that humans sink in water as they exhale.

Standard PH.8 a, b

The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include

- a) transformation of energy among forms including mechanical, thermal, electrical, gravitational, chemical, and nuclear; and
- b) efficiency of systems.

Essential Understandings

- Energy can be transformed from one form to another. (Example: Falling water turns a turbine that generates electricity and produces heat and light in a classroom.)
- *Efficiency* of a machine is the ratio of output work to input work.

Essential Knowledge and Skills**Skills**

- Illustrate that energy can be transformed from one form to another, using examples from everyday life and technology.
- Calculate efficiency by identifying the useful energy in a process.
- Qualitatively identify the various forms of energy transformations in simple demonstrations.

Standard PH.9 a

The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include

a) wave characteristics (period, wavelength, frequency, amplitude, and phase).

Essential Understandings

- Mechanical waves transport energy as a traveling disturbance in a medium.
- In a transverse wave, particles of the medium move in a direction perpendicular to the direction the wave travels.
- In a longitudinal wave, particles of the medium move in a direction parallel to the direction the wave travels.
- For harmonic waves, velocity equals the product of the frequency and the wavelength.
- Frequency and period are reciprocals of each other.

Essential Knowledge and Skills

Knowledge

- Period, wavelength, and frequency are measured in seconds, meters, and Hertz.

Skills

- Identify examples of longitudinal and transverse waves.
- Differentiate between transverse and longitudinal waves, using simple models (slinky, stadium waves).
- Illustrate period, wavelength, and amplitude on a graphic representation of a harmonic wave.
- Solve problems involving frequency, period, wavelength, and velocity.
- Distinguish between waves that are in-phase and those that are out-of-phase.

Standard PH.9 b, c

The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include

- b) fundamental wave processes (reflection, refraction, diffraction, interference, polarization, Doppler effect); and
- c) light and sound in terms of wave models.

Essential Understandings

- Waves are reflected and refracted when they encounter a change in medium or a boundary.
- The overlapping of two or more waves results in constructive or destructive interference.
- Polarizing filters can transmit one direction of polarized light and block the other.
- When source and observer are in relative motion, a shift in frequency occurs (Doppler effect).
- Sound is a longitudinal wave that travels through matter.
- Light is an electromagnetic wave (transverse) that can travel through matter as well as a vacuum.

Essential Knowledge and Skills

Knowledge

- *Reflection* is the change of direction of the wave in the original medium.
- *Refraction* is the change of direction (bending) of the wave in the new medium.
- *Diffraction* is the spreading of a wave around a barrier or an aperture.
- The pitch of a note is determined by the frequency of the sound wave.
- The color of light is determined by the frequency of the light wave.
- As the amplitude of a sound wave increases, the loudness of the sound increases.
- As the amplitude of a light wave increases, the brightness of the light increases.

Standard PH.9 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	<p><u>Skills</u></p> <ul style="list-style-type: none"><li>• Graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary.<li>• Graphically illustrate constructive and destructive interference.<li>• Identify a standing wave, using a string.

Standard PH.10 a, b

The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include

- a) the properties and behaviors of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays; and
- b) current applications based on the wave properties of each band.

Essential Understandings

- Frequency, wavelength, and energy vary across the entire electromagnetic spectrum.

Essential Knowledge and SkillsKnowledge

- The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone).
- Medium wavelengths (infrared) are used for heating and night-vision-enhancing devices.
- Visible light comprises a very narrow portion of the electromagnetic spectrum.
- Ultraviolet wavelengths (shorter than the visible spectrum) are responsible for sunburn.
- X-rays and gamma rays are the highest frequency and shortest wavelength and are used primarily for medical purposes.

Standard PH.11 a, b

The student will investigate and understand, in describing optical systems, how light behaves in the fundamental processes of reflection, refraction, and image formation. Key concepts include

- a) application of the laws of reflection and refraction; and
- b) construction and interpretation of ray diagrams.

Essential Understandings

- The ray model of light can be used to understand the behavior of optical systems.
- Light incident on a smooth plane surface is reflected such that the angle of incidence equals the angle of reflection.
- Light incident on a smooth surface is refracted (transmitted) in such a manner that the ratio of the sine of the angle of incidence and the sine of the angle of refraction equals a constant.

Essential Knowledge and SkillsKnowledge

- For a converging lens, the focal point is the point at which a beam of light parallel to the principal axis converges.
- For a diverging lens, the focal point is the point from which a beam of light parallel to the principal axis appears to originate.
- A real image is formed by converging lights rays and can be displayed on a screen.
- A virtual image can be seen by an observer but cannot be projected on a screen because the light does not actually emanate from the image.
- The focal point is the point at which rays converge or from which they appear to diverge in a lens or mirror.
- The index of refraction is the ratio of the speed of light in a vacuum to the speed of light in the medium.

Standard PH.11 a, b (continued)

Essential Understandings	Essential Knowledge and Skills
	<p><u>Skills</u></p> <ul style="list-style-type: none"><li>• Investigate propagation, refraction, and reflection, using the ray model of light.<li>• Construct ray diagrams to verify the laws of reflection and refraction.

Standard PH.11 c, d

The student will investigate and understand, in describing optical systems, how light behaves in the fundamental processes of reflection, refraction, and image formation. Key concepts include

- c) development and use of mirror and lens equations; and
- d) predictions of types, size, and position of real and virtual images.

Essential Understandings

- The mirror and thin lens equation can be used to calculate the position of the object or image based on the focal length of the mirror or lens.

Essential Knowledge and Skills**Skills**

- Solve problems dealing with object and image distance, object and image size, and focal length, using the lens and mirror equations.
- Illustrate characteristics of real and virtual images, using examples (lens and mirror).
- Identify the type (real and virtual) and size of image formed by concave lenses and by convex lenses when the object is located at various locations including inside the focal point, at the focal point, at twice the focal point, and beyond twice the focal point.

Standard PH.12 a, b

The student will investigate and understand how to use the field concept to describe the effects of gravitational, electric, and magnetic forces. Key concepts include

- a) inverse square laws (Newton's law of universal gravitation and Coulomb's law); and
- b) operating principles of motors, generators, transformers, and cathode ray tubes.

Essential Understandings

- The force found from Newton's law and Coulomb's law is dependent on the inverse square of the distance between two objects.
- The electrostatic force (Coulomb's law) can be either repulsive or attractive, depending on the sign of the charges.
- The gravitational force (Newton's law) is always an attractive force.
- The interaction of two particles can be described as a two-step process: the creation of a field by one of the particles and the interaction of the field with the second particle.

Essential Knowledge and SkillsKnowledge

- Newton's Law of Universal Gravitation states that every particle in the universe attracts every other particle in the universe. $F = G (m_1 m_2) / r^2$. (F is the force, G is the universal gravitation constant, m is the mass of the two particles, and r is the distance between them.)
- Coulomb's law states that the magnitude F of the electrostatic force exerted by one point charge on another point charge is directly proportional to the magnitudes of q₁ and q₂ of the charges and inversely proportional to the square of the distance r between them: $F = k (q_1 q_2) / r^2$.
- The rotation of the coil of a motor or a generator through a magnetic field is used to transfer energy.

Standard PH.13 a, b, c

The student will investigate and understand how to diagram and construct basic electrical circuits and explain the function of various circuit components. Key concepts include

- a) Ohm's law;
- b) series, parallel, and combined circuits; and
- c) circuit components including resistors, batteries, generators, fuses, switches, and capacitors.

Essential Understandings

- Current is the flow of electrical charge.
- Voltage in a circuit provides the energy that drives the current.
- Elements in a circuit are positioned relative to other elements either in series or parallel.

Essential Knowledge and SkillsKnowledge

- According to Ohm's law, the resistance equals the voltage divided by the current.
- Voltage difference is change in electrical potential energy per unit charge.

Skills

- Recognize a series and a parallel circuit.
- Apply Ohm's law to a series and a parallel circuit.
- Assemble simple circuits composed of batteries and resistors in series and in parallel.
- Solve simple circuits using Ohm's law.

Standard PH.14 a, b, c, d

The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied by Newtonian physics. Key concepts include

- a) wave/particle duality;
- b) wave properties of matter;
- c) matter/energy equivalence; and
- d) quantum mechanics and uncertainty.

Essential Understandings

- For processes that are important on the atomic scale, objects exhibit both wave characteristics (e.g., interference) as well as particle characteristics (e.g., discrete amounts and a fixed definite number of electrons per atom).
- The special theory of relativity predicts that energy and matter can be converted into each other.

Essential Knowledge and SkillsKnowledge

- Electrons rotating around the nucleus of an atom can be treated as standing waves in order to model the atomic spectrum.
- The dramatic examples of the mass-energy transformation are the fusion of hydrogen in the sun, which provides light and heat for the earth, and the fission process in nuclear reactors that provide electricity.
- Quantum mechanics requires an inverse relationship between the measurable location and the measurable momentum of a particle. The more accurately one determines the position of a particle, the less accurately the momentum can be known, and vice versa. This is known as the Heisenberg uncertainty principle.

Standard PH.14 e, f, g, h, i

The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts include

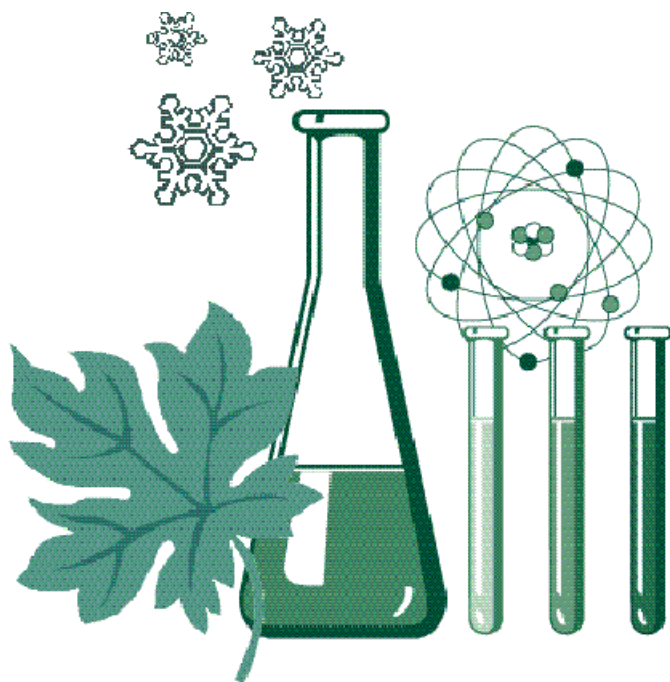
- e) relativity;
- f) nuclear physics;
- g) solid state physics;
- h) superconductivity; and
- i) radioactivity.

Essential Understandings

- The motion of objects traveling near or approaching the speed of light does not follow Newtonian mechanics but must be treated within the theory of relativity.
- Nuclear physics is the study of the interaction of the protons and neutrons in the atom's nucleus.
- Natural radioactivity is the spontaneous disintegration of unstable nuclei.
- Atoms and molecules bind together in regular arrays to form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.).
- Certain materials at very low temperatures exhibit the property of zero resistance called *superconductivity*.

Essential Knowledge and SkillsKnowledge

- Objects cannot travel faster than the speed of light.
- The nuclear force binds protons and neutrons in the nucleus.
- Alpha, beta, and gamma are different emissions associated with radioactive decay.
- *Fission* is the breakup of heavier nuclei to lighter nuclei.
- *Fusion* is the combination of lighter nuclei to heavier nuclei.
- Many substances in the natural world have a crystal structure, including most metals and minerals.



Science Standards of Learning Curriculum Framework

Appendix

Commonwealth of Virginia
Board of Education
Richmond, Virginia
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APPENDIX Science Skill Scope and Sequence

OBSERVING:

To perceive, using one or more of the senses

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	a) basic properties of objects are identified by direct observation b) observations are made from multiple positions to achieve different perspectives
1st Grade	a) differences in physical properties are observed using the senses b) simple tools are used to enhance observations
2nd Grade	a) observation is differentiated from personal interpretation, and conclusions are drawn based on observations b) observations are repeated to ensure accuracy
3rd Grade	a) predictions and observations are made [repeated under PREDICTING]
4th Grade	a) distinctions are made among observations, conclusions, inferences, and predictions [repeated under PREDICTING]
5th Grade	
6th Grade	a) observations are made involving fine discrimination between similar objects and organisms
Life Science	
Physical Science	
Earth Science	
Biology	a) observations of living things are recorded in the lab and in the field
Chemistry	
Physics	b) instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge [repeated under MEASURING]

CLASSIFYING AND SEQUENCING:

To arrange or distribute objects, events, or ideas according to some method or system

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	d) a set of objects is sequenced according to size e) a set of objects is separated into two groups based on a single physical attribute
1st Grade	c) objects or events are classified and arranged according to attributes or properties
2nd Grade	c) two or more attributes are used to classify items
3rd Grade	b) objects with similar characteristics are classified into at least two sets and two subsets k) natural events are sequenced chronologically
4th Grade	
5th Grade	a) rocks, minerals, and organisms are identified using a classification key
6th Grade	b) a classification system is developed based on multiple attributes
Life Science	
Physical Science	
Earth Science	
Biology	
Chemistry	
Physics	

COMMUNICATING:

To gather, record, and transmit qualitative or quantitative information, including defining operationally; using expert, print, and electronic resources; gathering, charting, recording, and graphing data; and presenting information in standard written narrative, oral, audiovisual, and electronic formats

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	c) objects are described both pictorially and verbally h) picture graphs are constructed using 10 or fewer units
1st Grade	d) observations and data are communicated orally and with simple graphs, pictures, written statements, and numbers
2nd Grade	f) picture and bar graphs are constructed using numbered axes
3rd Grade	g) data are gathered, charted, and graphed (line plot, picture graph, and bar graph)
4th Grade	f) data are displayed using bar and basic line graphs
5th Grade	e) data are collected, recorded, and reported using the appropriate graphical representation (graphs, charts, diagrams)
6th Grade	i) data are organized and communicated through graphical representation (graphs, charts, and diagrams)
Life Science	a) data are organized into tables showing repeated trials and means
Physical Science	d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and spring scales are used to gather data [repeated under MEASURING] e) numbers are expressed in scientific notation where appropriate f) research skills are utilized using a variety of resources m) experimental results are presented in appropriate written form
Earth Science	c) scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted [repeated under MODELING]
Biology	i) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results [repeated under ANALYZING DATA] j) research utilizes scientific literature
Chemistry	
Physics	a) the components of a system are defined c) information is recorded and presented in an organized format .2a) a description of a physical problem is translated into a mathematical statement in order to find a solution (repeated under ANALYZING DATA)

MEASURING:

To develop a comparative or quantitative description of properties such as mass, length, volume, and temperature

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	f) nonstandard units are used to measure common objects
1st Grade	e) length, mass, and volume are measured using standard and nonstandard units
2nd Grade	e) length, volume, mass, and temperature measurements are made in metric units (centimeters, meters, liters, degrees Celsius, grams, kilograms) and standard English units (inches, feet, yards, cups, pints, quarts, gallons, degrees Fahrenheit, ounces, pounds)
3rd Grade	e) length is measured to the nearest centimeter f) mass is measured to the nearest gram d) volume is measured to the nearest milliliter and liter h) temperature is measured to the nearest degree Celsius i) time is measured to the nearest minute
4th Grade	e) appropriate metric measures are used to collect, record, and report data d) appropriate instruments are selected to measure linear distance, volume, mass, and temperature
5th Grade	c) appropriate instruments are selected and used for making quantitative observations of length, mass, volume, and elapsed time d) accurate measurements are made using basic tools (thermometer, meter stick, balance, graduated cylinder)
6th Grade	c) precise and approximate measurements are recorded h) data are collected, recorded, analyzed, and reported using appropriate metric measurement
Life Science	c) metric units (SI — International System of Units) units are used
Physical Science	b) length, mass, volume, density, temperature, weight, and force are accurately measured and reported using metric units (SI — International System of Units) c) conversions are made among metric units, applying appropriate prefixes d) triple beam and electronic balances, thermometers, metric rulers, graduated cylinders, and spring scales are used to gather data [repeated under COMMUNICATING]
Earth Science	a) volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools
Biology	
Chemistry	g) ...SI units...[are used]

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Physics	b) instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge [repeated under OBSERVING] d) metric units are used in all measurements and calculations g) data gathered from non-SI instruments are incorporated through appropriate conversions

PREDICTING:

To forecast a possible result on the basis of information acquired from systematic observations, scientific principles, and laws

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	i) an unseen member in a sequence of objects is predicted
1st Grade	f) predictions are based on patterns of observation rather than random guesses
2nd Grade	
3rd Grade	a) predictions and observations are made
4th Grade	a) distinctions are made among observations, conclusions, inferences, and predictions [repeated under OBSERVING] h) predictions are made based on data from picture graphs, bar graphs, and basic line graphs [repeated under ANALYZING DATA]
5th Grade	f) predictions are made using patterns, and simple graphical data are extrapolated [repeated under ANALYZING DATA] b) estimations of length, mass, and volume are made
6th Grade	f) a method is devised to test the validity of predictions and inferences d) scale models are used to estimate distance, volume, and quantity [repeated under MODELING]
Life Science	h) continuous line graphs are constructed, interpreted, and used to make predictions [repeated under ANALYZING DATA]
Physical Science	
Earth Science	
Biology	
Chemistry	
Physics	.2d) interpolated, extrapolated, and analyzed trends are used to make predictions [repeated under ANALYZING DATA]

HYPOTHESIZING:

To make a testable prediction about the relationship between variables in a system

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	g) a question is developed from one or more observations
1st Grade	
2nd Grade	d) conditions that influence a change are defined
3rd Grade	c) questions are developed to formulate hypotheses
4th Grade	b) hypotheses are formulated based on cause-and-effect relationships
5th Grade	
6th Grade	e) hypotheses are stated in ways that identify the independent (manipulated) and dependent (responding) variables
Life Science	g) variables are controlled to test hypotheses, and trials are repeated [repeated under USING VARIABLES]
Physical Science	
Earth Science	
Biology	b) hypotheses are formulated based on direct observations and information from the scientific literature
Chemistry	
Physics	

INFERRING:

To derive a reasoned conclusion based on verifiable evidence and systematic observations

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	
1st Grade	h) inferences are made and conclusions are drawn about familiar objects and events
2nd Grade	b) observation is differentiated from personal interpretation, and conclusions are drawn based on observations [repeated under OBSERVING]
3rd Grade	j) inferences are made and conclusions are drawn
4th Grade	a) distinctions are made among observations, conclusions, inferences, and predictions [repeated under PREDICTING]
5th Grade	
6th Grade	f) a method is devised to test the validity of predictions and inferences [repeated under USING VARIABLES]
Life Science	
Physical Science	k) valid conclusions are made after analyzing data [repeated under ANALYZING DATA]
Earth Science	
Biology	e) conclusions are formed based on recorded quantitative and qualitative data
Chemistry	
Physics	

USING VARIABLES IN EXPERIMENTATION:

To change one variable intentionally under controlled conditions

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	
1st Grade	g) simple experiments are conducted to answer questions
2nd Grade	
3rd Grade	
4th Grade	c) variables that must be held constant in an experimental situation are defined
5th Grade	g) manipulated and responding variables are identified
6th Grade	g) one variable is manipulated over time, using many repeated trials
Life Science	b) variables are defined e) sources of experimental error are identified f) dependent variables, independent variables, and constants are identified g) variables are controlled to test hypotheses, and trials are repeated
Physical Science	g) independent and dependent variables, constants, controls, and repeated trials are identified l) research methods are used to investigate practical problems and questions
Earth Science	d) variables are manipulated with repeated trials
Biology	c) variables are defined and investigations are designed to test hypotheses
Chemistry	a) designated laboratory techniques d) manipulation of multiple variables, using repeated trials
Physics	e) the limitations of the experimental apparatus and design are recognized f) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges

DESIGNING, CONSTRUCTING, AND INTERPRETING MODELS:

To build a mental or physical representation of an idea for explanation and interpretation

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	
1st Grade	
2nd Grade	h) simple physical models are constructed
3rd Grade	
4th Grade	
5th Grade	
6th Grade	d) scale models are used to estimate distance, volume, and quantity [repeated under PREDICTING] j) models are designed to explain a sequence
Life Science	d) models are constructed to illustrate and explain phenomena
Physical Science	
Earth Science	b) technologies, including computers, probeware, and global positioning systems (GPS), are used to collect analyze, and report data and to demonstrate concepts and simulate experimental conditions [repeated under ANALYZING DATA] c) scales, diagrams, maps, charts, graphs, tables, and profiles are constructed and interpreted [repeated under COMMUNICATING]
Biology	k) differentiation is made between a scientific hypothesis and theory
Chemistry	
Physics	.2a) a description of a physical problem is translated into a mathematical statement in order to find a solution [repeated under ANALYZING DATA]

INTERPRETING, ANALYZING, AND EVALUATING DATA:

To explain information, determine its essential features and meaning, and critically judge which data are meaningful or useful to the matter being studied

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Kindergarten	j) unusual or unexpected results in an activity are recognized
1st Grade	
2nd Grade	g) unexpected or unusual quantitative data are recognized
3rd Grade	
4th Grade	h) predictions are made based on data from picture graphs, bar graphs, and basic line graphs [repeated under PREDICTING] g) numerical data that are contradictory or unusual in experimental results are recognized
5th Grade	f) predictions are made using patterns, and simple graphical data are extrapolated [repeated under PREDICTING]
6th Grade	f) a method is devised to test the validity of predictions and inferences
Life Science	h) continuous line graphs are constructed, interpreted, and used to make predictions [repeated under PREDICTING] i) interpretations from a set of data are evaluated and defended
Physical Science	h) data tables showing the independent and dependent variables, derived quantities, and the number of trials are constructed and interpreted; i) data tables for descriptive statistics showing specific measures of central tendency, the range of the data set, and the number of repeated trials are constructed and interpreted; j) frequency distributions, scattergrams, line plots, and histograms are constructed and interpreted k) valid conclusions are made after analyzing data
Earth Science	b) technologies including computers, probeware, and global positioning systems (GPS), are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions [repeated under MODELING] e) a scientific viewpoint is constructed and defended (the nature of science)

Grade/Subject	Skill statements from the “Scientific Investigation, Reasoning, and Logic” Strand
Biology	d) graphing and arithmetic calculations are used as tools in data analysis e) conclusions are formed based on recorded quantitative and qualitative data [repeated under INFERRING] f) sources of error inherent in experimental design are identified and discussed g) validity of data is determined l) alternative scientific explanations and models are recognized and analyzed i) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results [repeated under COMMUNICATING]
Chemistry	e) accurate recording, organizing, and analysis of data through repeated trials f) mathematical and procedural error analysis g) mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis) h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data and communicating results i) the use of appropriate technology including computers, graphing calculators, and probeware, for gathering data and communicating results
Physics	.2a) a description of a physical problem is translated into a mathematical statement in order to find a solution [repeated under MODELING] .2b) relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data .2c) the slope of a linear relationship is calculated and includes appropriate units .2d) interpolated, extrapolated, and analyzed trends are used to make predictions .2e) analysis of systems employs vector quantities utilizing trigonometric and graphical methods .1h) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results